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**FOR ENGINEERS, ELECTRICIANS
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Fully illustrated with diagrams and sketches.

Including calculations and tables for ready reference.

Helpful questions and answers. Trial tests
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Design, construction, operation and maintenance
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Based on the best knowledge and experience
of applied electricity.

by **FRANK D. GRAHAM, B.S., M.S., M.E., E.E.**



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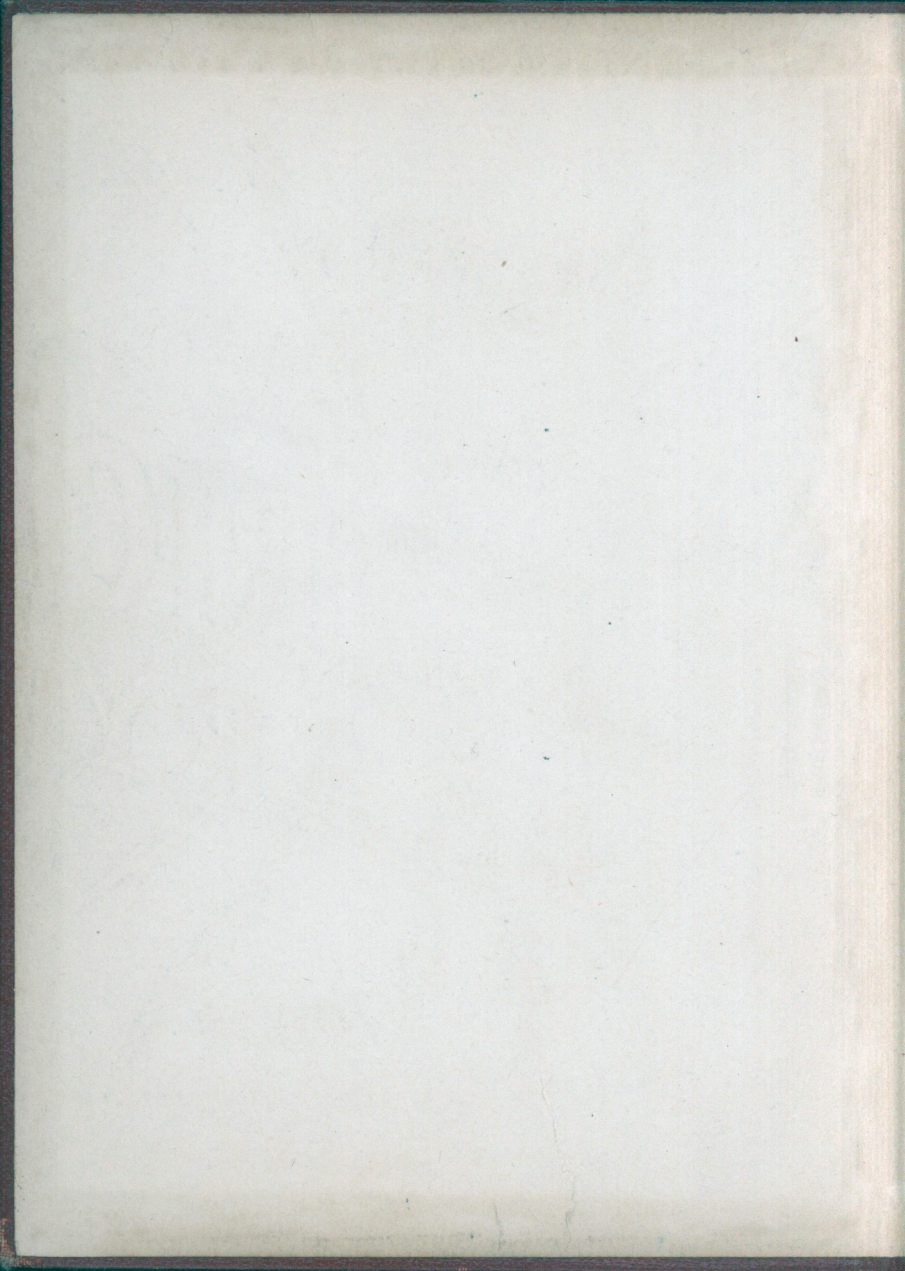
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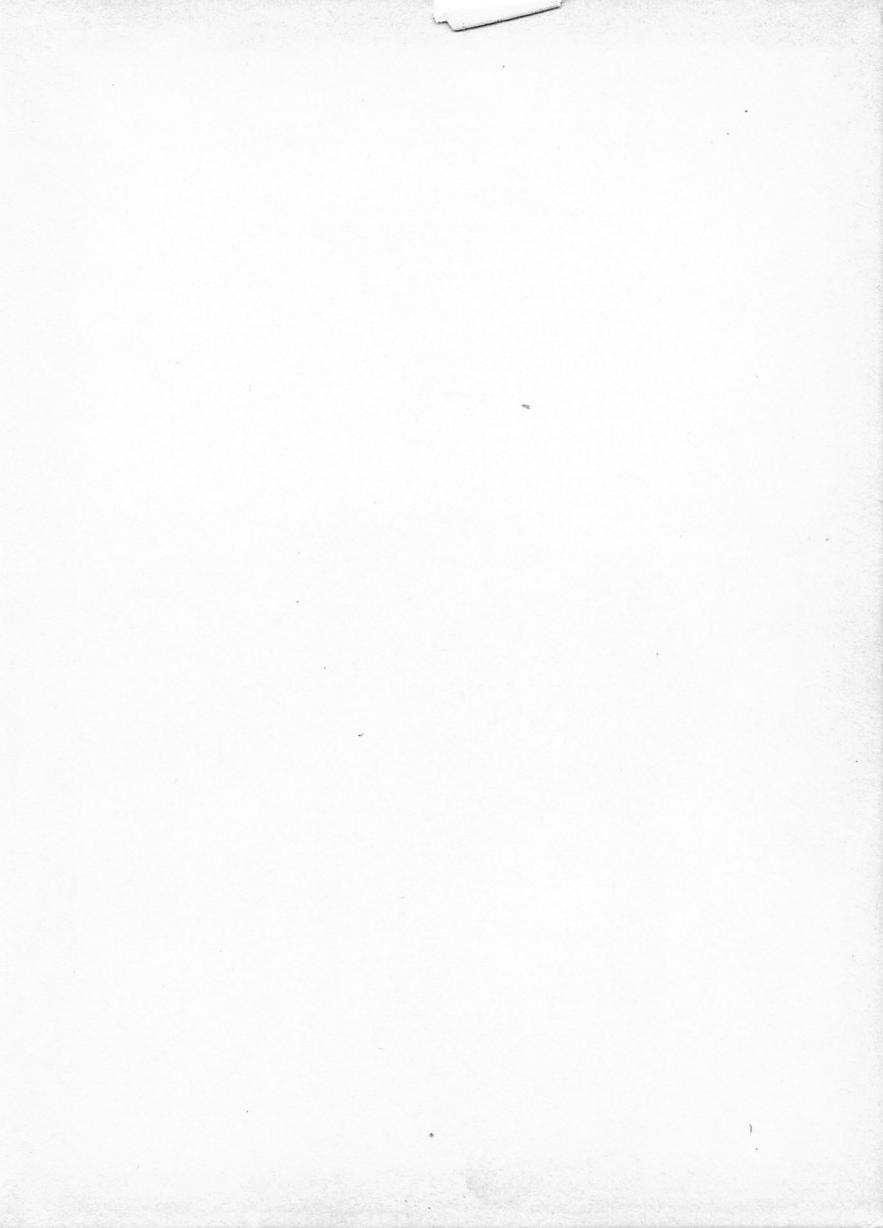


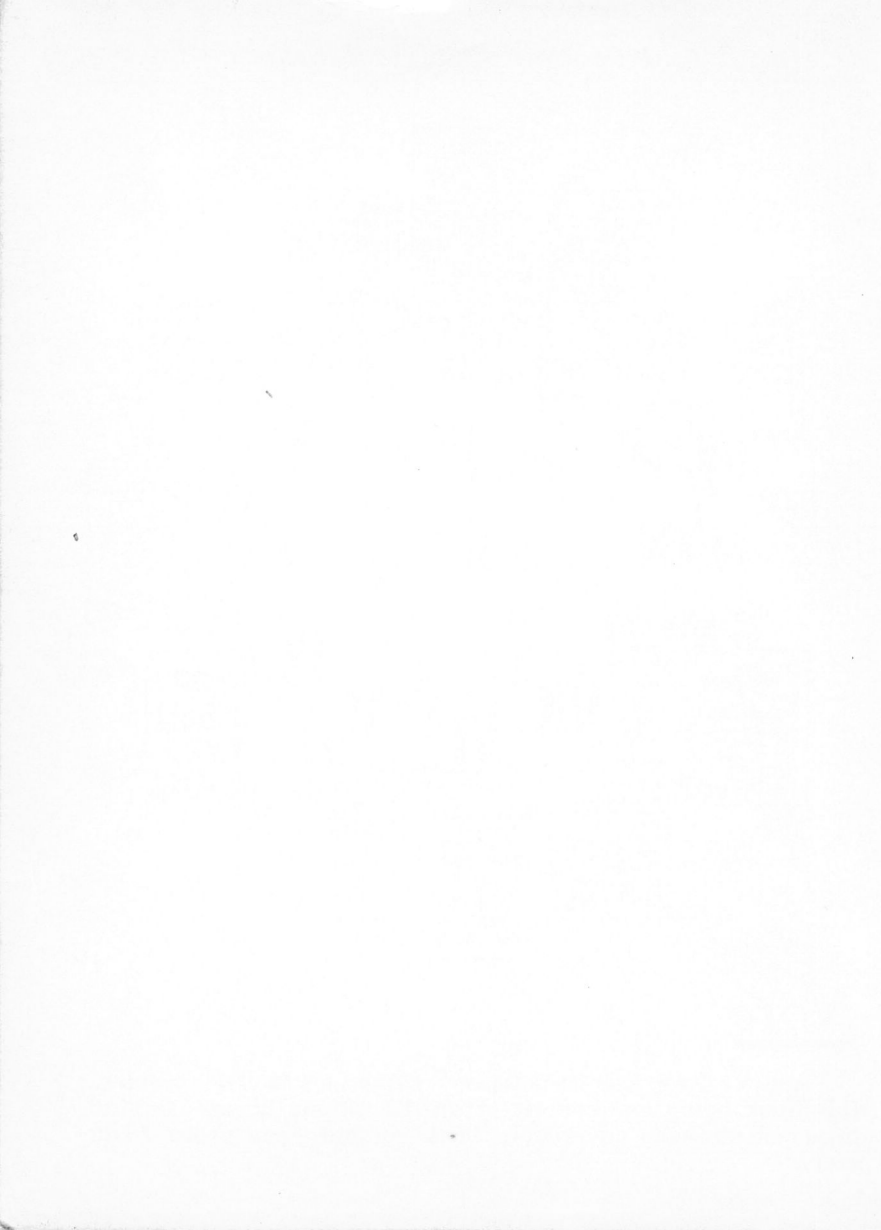
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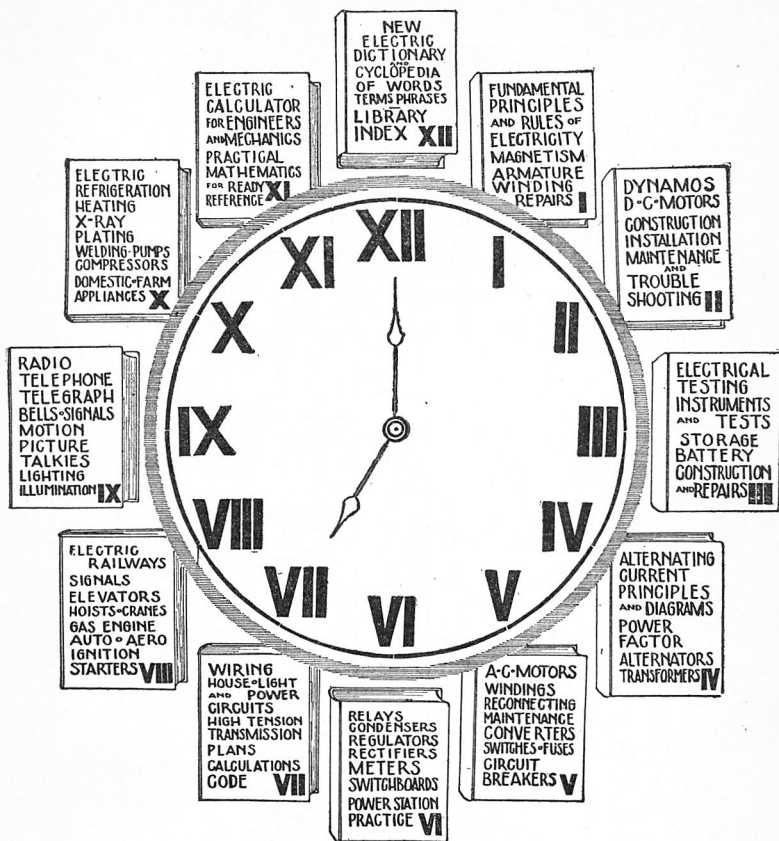
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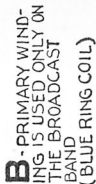


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Foreword



This series is dedicated to Electrical Progress—to all who have helped and those who may in the coming years help to bring further under human control and service to humanity this mighty force of the Creator.

The Electrical Age has opened new problems to all connected with modern industry, making a thorough working knowledge of the fundamental principles of applied electricity necessary.

The author, following the popular appeal for practical knowledge, has prepared this progressive series for the electrical worker and student; for all who are seeking electrical knowledge as a life profession; and for those who find that there is a gap in their training and knowledge of Electricity.

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The author and publishers here gratefully acknowledge the hearty and generous help and co-operation of all those who have aided in developing this helpful series of Educators.

The series will speak for itself and "those who run may read."

The Publishers.

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Finder



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To quickly and easily find information on any subject, read over the general chapter headings as shown in the large type—this brings the reader's attention to the general classification of information in this book.

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*"An hour with a book would have brought to your mind,
The secret that took the whole year to find;
The facts that you learned at enormous expense,
Were all on a library shelf to commence."*

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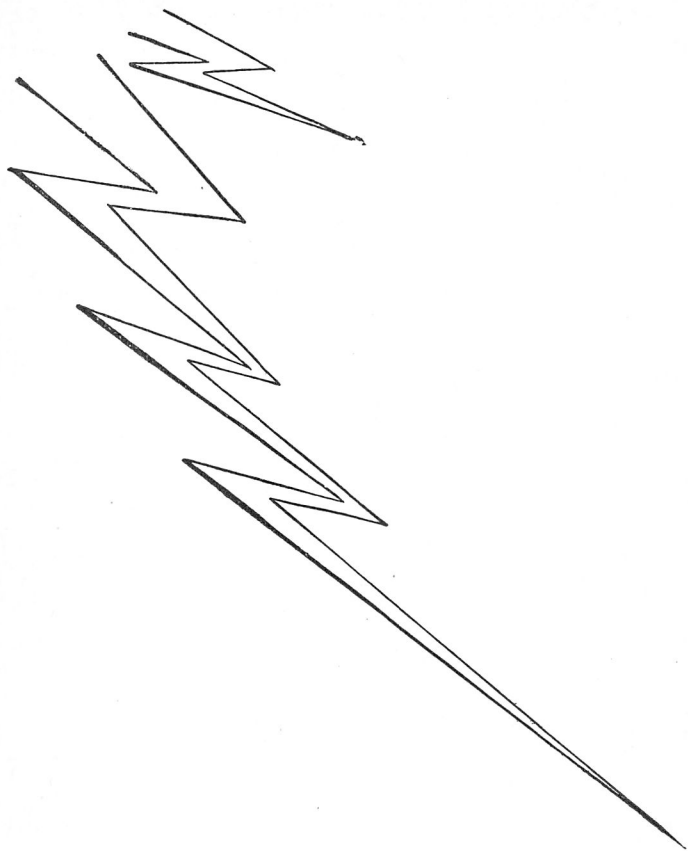
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CHAPTER 174

Radio Principles

Dr. Albert Einstein discards the theory of the ether usually presented by writers in an attempt to explain radio transmission. Dr. Einstein derides radio's ethereal medium as fiction, calling it a makeshift fabricated to explain something for which scientists have not had the correct explanation. Einstein believes it is *an electro-magnetic phenomenon*; so did Charles Proteus Steinmetz.

Shortly before his death Steinmetz said: "*There are no ether waves.*" He explained that radio and light waves are merely properties of an alternating electro-magnetic field of force which extends through space. Scientists, he contended, need no idea of ether. They can think better in the terms of electro-magnetic waves.

If a coil of insulated wire surround a piece of soft iron and a direct current be sent through the coil, it is called an electro-magnet. The space around the coil is the magnetic field. When the current is increased the magnetic field increases. When the current is decreased the breadth of the field is reduced. If the current be reversed, the field is reversed. When an alternating current is sent through the coil the magnetic field alternates. The field becomes a periodic phenomenon or a wave, described by Steinmetz as "an alternating magnetic field wave."

Steinmetz, like Einstein, pointed out that the conception of the ether is one of those hypotheses made in an attempt to explain some scientific difficulty. He declared that the more study is applied to the ether theory

the more unreasonable and untenable it becomes. He held it to be merely conservatism or lack of courage which has kept science from abandoning the ethereal hypothesis.

Steinmetz called attention to the fact that belief in an ether is in contradiction to the relativity theory of Einstein, since this theory holds that there is no absolute position or motion, but that all positions and motions are relative and equivalent. Thus, if science agreed that the theory of relativity is correct the ether theory must be abandoned.

No space will be wasted here in talking about ether waves. The space surrounding a wire that carries an electric current *is an electro-magnetic field, that is, a combination of a magnetic field and an electrostatic field.*

If the current and voltage alternate, the electro-magnetic field alternates; that is, it is a periodic field or an electro-magnetic wave. Thus, the broadcast listener who wants to forget the ether can think of the aerial wire at the transmitter, setting up electro-magnetic waves in a field of electric force, which now, the theories contend, fills all space and therefore every receiving wire is within the field. This field, however, is supposed to be in a state of rest until the broadcast transmitter causes it to vibrate.

The action of the transmitter is like tapping a mold of jello. Waves pass through it, and so radio waves are produced in the electro-magnetic field.

The transmitter taps the hypothetical medium, causing it to vibrate. The receiving set is designed to detect the vibrations and so intelligence is carried from one point to another.

It is well known that a stone thrown into a pond *causes ripples or waves on the surface of the water, which move away*

NOTE.—*As stated by Dr. Lee de Forest:* Radio is simply a cause and an effect. The *cause* is the radio transmitter. It makes an electro-magnetic splash that sets up radio waves. These waves travel through space in all directions. The *effect* is the setting up of delicate currents in the aerial or loop. These delicate currents are detected and converted into audible sounds by means of the radio receiving set. Imagine a boy operating a paddle at one end of a pond of still water. Ripples are set up in the water. They travel farther and farther away from the paddle, getting weaker as they move along until they reach a piece of wood which bobs up and down as it rides the waves. Put a bell on the piece of wood, in order that it will ring with the action of the waves, this illustrates the mechanical parallel of radio communication.

from the point of disturbance in concentric circles of ever increasing diameters until they reach the shore. The number of waves breaking on the shore in one second is called the *frequency* of the wave motion, and the distance between them measured from crest to crest, is the *wave length*.

The waves are strongest at the point of disturbance and gradually become weaker as they travel away from that point, as shown in figs. 7,180 and 7,181. If the distance be sufficiently great they will become so weak as to be invisible.

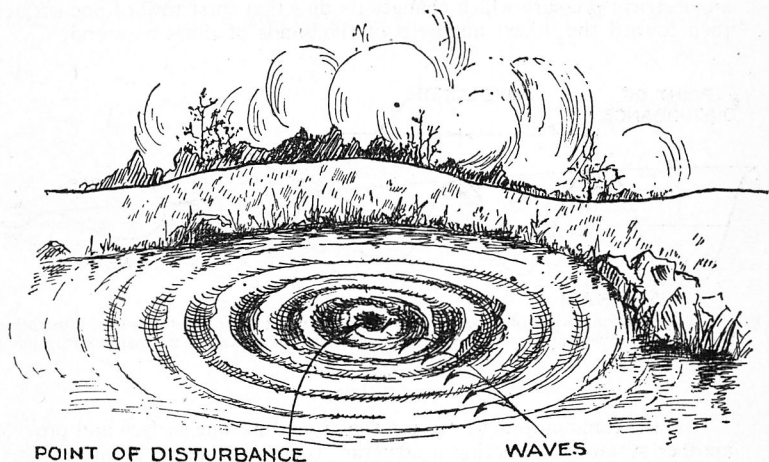


FIG. 7,180.—Effect of throwing stone in still water; production of waves which radiate or travel from the point where stone enters the water, or “point of disturbance.”

NOTE.—According to Marconi radio waves go to outer space. In his inaugural address at the second meeting of the Italian Society for the Advancement of Science Sept. 11, 1930, Sen. Guglielmo Marconi expressed belief that radio waves may travel long distances, even millions of miles, beyond the earth's atmospheric layer. He said that he did not see any reason why, as some scientists maintain, waves produced on the earth should not travel such a distance, since light and heat waves reach the earth from the sun, penetrating the atmospheric layer. He referred to observations of such scientists as Stormer and Pedersen and commented that the former had said that electrified particles derived from the sun and under the magnetic influence of the earth acted as a reflector of electric waves from the earth after they had passed the so called Kenelly-Heaviside layer.

Radio communication as has been explained is *a form of wave motion which occurs in an electro-magnetic field, these waves acting in a similar manner to water waves.*

In radio communication it is first necessary to create electro-magnetic waves in varying groups and of varying strength, and second to intercept them with apparatus capable of changing them to sound waves.

To create the waves it is necessary to have two surfaces separated by a distance of from ten to several hundred feet and to create between them an electrical pressure which changes its direction (first toward one surface then toward the other) hundreds of thousands of times a second.

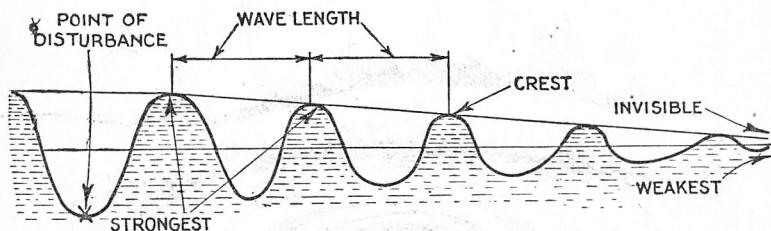


FIG. 7,181.—Sectional view of waves produced by throwing stone in still water, illustrating crest of wave, wave length and gradual weakening of the waves as they travel from the point of disturbance.

It is the common practice to use the ground for one surface and provide another surface by erecting a structure composed of one or more wires, insulated from the earth and suspended many feet above it.

Between these, by means of suitable transmitting equipment an electrical pressure is produced of from one to twenty volts which starts waves radiating out in all directions. These pressure waves are, however, only part of a radio wave. From any wire in which current is flowing are radiated electro-magnetic waves and radio waves are made up then, of both electro-magnetic and pressure electrostatic waves.

Comparing these waves to the action of hurling a rock into a pool of water, the amperes of electric current put into the antenna correspond to the size of the rock, while the volts of electrical pressure are equivalent to the force with which the rock is hurled. The larger the rock and the

greater the force behind it, the bigger the splash and consequent waves. The more amperes of current flowing in the antenna circuit and the greater the pressure (volts) between antenna and ground, the stronger the waves radiated. These radio waves have similar characteristics to another class of waves—sound waves.

When the note C is struck on the piano (as in fig. 7,182) the sound waves vibrate 256 times per second and either a C tuning fork or a wire tuned to C and in the immediate vicinity will vibrate 256 times per second also. The two wires are said to be in resonance.

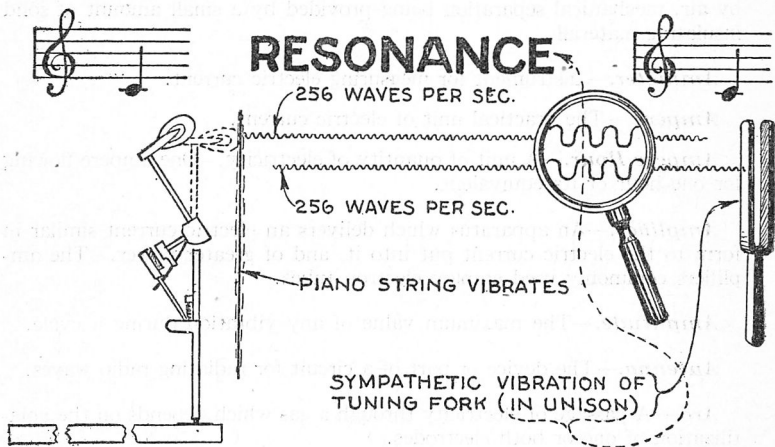


FIG. 7,182.—Sympathetic vibration of tuning fork with struck piano string when tuned to same pitch, illustrating the wave theory of radio.

The waves radiated by a radio transmitter always have a definite number per second and in order to hear a station, the receiving equipment must be put in resonance with the waves radiated by the transmitter. This operation is known as tuning.

Technical Terms.—For the convenience of the student definitions of the terms commonly used are here given; the list should be used as a reference in studying the text.

Radio Definitions

A. C.—Alternating current.

A. C. C. W.—Alternating current continuous waves.

Aerial.—A device for receiving radio waves.

A. F.—Audio frequency.

Air Condenser.—A condenser in which the metal plates are separated by air, mechanical separation being provided by a small amount of solid insulating material.

Ammeter.—Instrument for measuring electric current.

Ampere.—The practical unit of electric current.

Ampere Hour.—A unit of quantity of electricity. One ampere flowing for one hour or its equivalent.

Amplifier.—An apparatus which delivers an electric current similar in form to the electric current put into it, and of greater power. The amplifiers commonly used employ electron tubes.

Amplitude.—The maximum value of any vibration during a cycle.

Antenna.—The device or part of a circuit for radiating radio waves.

Arc.—A passage of electricity through a gas which depends on the volatilization of one or both electrodes.

Arc Transmission.—The transmission of radio messages by continuous waves produced by an electric arc.

Atmosphere.—Disturbances caused in a radio receiving set by atmospheric electricity. They cause grinding or crashing sounds in the telephone receiver and at times interfere with reception.

Audion.—A three element vacuum tube.

Audio Frequency.—The term applied to currents pulsating at a frequency not over 10,000 cycles per second. Frequencies within the range of the human ear.

Battery.—Two or more electric cells connected together in one unit.

Beats.—Periodic variations in the amplitude of two vibrations of slightly different frequencies due to the interaction of the two.

Break-in.—An arrangement whereby the transmitting key automatically disconnects the receiving set from the aerial and substitutes the transmitting set.

Broadcasting.—The transmission of information, entertainment, etc., intended for an unlimited audience.

Buzzer.—A type of electro-magnetic interrupter.

By-pass.—A condenser used for providing a low impedance path for high frequency currents across low frequency apparatus.

Capacity.—Electrical quality of a condenser or an antenna, somewhat analogous to elasticity or springiness.

Cathode Rays.—The stream of electrons or electrical particles sent out from the cathode or filament of a vacuum tube. These rays are negatively charged.

Circuit.—The wires and instruments taken collectively when connected for a given purpose.

Code, International.—The conventional arrangement of dots and dashes representing the letters of the alphabet, figures, etc., for the transmission of intelligence by radio telegraphy.

Coil Aerial.—An aerial consisting of one or more complete turns of wire.

Condenser.—An apparatus consisting of insulating material (which may be air) between two metal plates or sets of plates. The purpose of a condenser is to provide capacity.

Condenser Antenna.—An antenna consisting of two condenser plates, one of which may be a wire or set of wires elevated above the ground, and the other of which may be either the ground or another set of wires. The wire or set of wires elevated above the ground is only a part of the whole antenna.

Continuous Waves.—Radio waves which do not vary in amplitude (intensity). Continuous waves are not modulated, as modulation varies the wave amplitude.

Crystal Detector.—A device which makes incoming signals audible in the telephone receiver, employing a mineral across the contact with which more current can flow in one direction than the opposite.

Counterpoise.—A set of metal wires or sheet forming the lower plate of a condenser antenna.

Coupler.—A device by means of which the coupling between circuits can be varied in a receiving set having more than one circuit. It usually consists of two coils of wire so arranged that one coil can slide or rotate within or near the other.

Cycle.—A complete reversal of the current in an *a.c.* circuit.

Damped Wave.—Radio waves that come in groups, the successive waves in each group decreasing in magnitude. Damped waves are produced by spark transmitting sets.

Design.—The electrical design of a circuit is the specification of particular values for the various constituent parts of that circuit.

Detector.—A device which converts radio-frequency current into pulsating current in one direction so as to make signals audible in the telephone receiver.

Dielectric.—Any material which offers a very high resistance to the passage of electric current.

Down Lead.—The wire connection from the aerial to the receiving set. (Also called "lead-in.")

Electrolyte.—The active liquid in an electric battery.

Electro-magnet.—A temporary magnet which is magnetized by the passage of an electric current through a wire wound around it.

Electrostatic.—Pertaining to an electrically charged body in which no current flows.

Electron Tube.—A combination of a filament which may be heated, a metal plate, and a metal grid which controls the flow of electrons from the filament to the plate, the whole in a vacuum. The usual type of electron tube used as a detector or amplifier greatly resembles in appearance an incandescent lamp bulb. (This is called by various names, such as "audion" "vacuum tube" "triode," "three-electrode tube.")

***Ether.**—The hypothetical medium through which radio waves are said to be propagated through space.

Fading.—Irregular variation of intensity of signals caused by actual variation of wave intensity.

*NOTE.—Dr. Albert Einstein discards the theory of the ether usually presented by radio writers. See page 4,441.

Farad.—A unit of electric capacity. If a steady current of one ampere flow into a condenser and the voltage across the condenser be one volt at the end of one second, the capacity of that condenser is one farad.

Feed back.—The energy returned to the grid, and the means for returning it, in a regenerative circuit.

Filament.—The hot element in a vacuum tube which emits the electrons.

Fleming Valve.—A two-element vacuum tube.

Frequency.—The number of complete reversals, or cycles per second.

Generator.—A commonly used but objectionable name for a machine which converts mechanical energy into electric energy.

Grid.—The control electrode in a three element vacuum tube.

Grid bias.—A negative pressure applied to the grid.

Grid leak.—A high resistance connecting the grid to the filament.

Ground.—An electrical connection to earth or to a large conductor which is at the earth's pressure.

Ground Wire.—The wire connection from the receiving set to ground or counterpoise.

Hard Tube.—An electron tube suitable for use as an amplifier. A tube having a higher vacuum than is necessary for a detector.

Harmonics.—Waves, the frequency of which is a multiple of the main wave of a transmitting station. Harmonics are usually objectionable; the power that goes into them is wasted.

Heaviside layer.—An assumed layer of ionized gas supposed to exist at an elevation of 25 or more miles above the earth's surface.

Henry.—The practical unit of inductance.

Heterodyne.—To produce beats with an incoming C. W. signal by supplying a locally generated frequency.

Honeycomb.—A type of winding for inductance coils which resembles a honeycomb.

NOTE.—*The Kenelly-Heaviside layer*, first postulated in 1902 by Oliver Heaviside, English physicist, and A. E. Kenelly, and proved to exist in 1925 by other scientists, is a conducting layer of ionized gas at a level of forty to fifty kilometers (twenty-five to thirty-one miles) above the earth's surface during the day, rising to about nine kilometers (fifty-six miles) at night. Its existence was pointed to be the behavior of long wave length radio waves.

Hydrometer.—An instrument for measuring the specific gravity of liquids.

I. C. W.—Interrupted continuous waves.

Impedance.—The total opposition offered by a circuit to the passage of a current. The ratio of the voltage to the current produced by it.

Impulse.—A force acting for a very short time, such as a quick blow.

Inductance.—Electrical quality of a circuit or part of a circuit, somewhat analogous to heaviness or inertia.

Insulator.—Any substance which does not pass an electric current.

Interference.—Any electrical disturbance originating outside the receiving set which prevents clear reception of the desired signal.

Interrupter.—A device which intermittently breaks or interrupts an electric current.

Key.—A type of switch by means of which the current may be stopped and started for signaling.

Kilocycle.—1,000 cycles.

Lead-in.—Same as down lead.

Line Radio.—Transmission of a high frequency current, with its accompanying wave field, guided by a conducting line.

Loading Coil.—A coil of wire for increasing the inductance (and hence the resonance wave length) of an antenna or other circuit.

Loop aerial.—Same as coil aerial. (There is some tendency to restrict "loop aerial" to a single turn coil.)

Megohm.—The unit used to measure high resistances. One megohm equals 1,000,000 ohms.

Meter.—A unit of length 39.37 inches. The usual unit for expressing wave lengths.

Microfarad.—The unit of electrical capacity used to designate the capacity of condensers. It is one-millionth part of a farad. The higher the microfarad rating of a condenser the larger its capacity.

Microphone.—The apparatus which picks up the sound waves at a broadcasting station and produces corresponding electrical variations in the battery or transformer circuit of the transmitter.

Milli-henry.—.001 henry.

Modulation.—Variation of amplitude of the radio wave, the variation being at an audible frequency.

Motor-generator.—A combined motor and generator by means of which a *d.c.* voltage may either be stepped up to a higher value or stepped down to a lower.

Natural frequency.—The frequency with which a coil is in tune by virtue of its inductance and distributed capacity.

Ohm.—The unit of electrical resistance. With the voltage remaining constant, the current flowing in a circuit is inversely proportional to the resistance in the circuit. In other words—the higher the resistance, the smaller the current and vice versa.

Open Antenna.—Same as condenser antenna.

Oscillator.—An electrical circuit for the generation of oscillations or high frequency currents.

Oscillations.—Very rapid vibrations.

Phase.—The time elapsed from the beginning of a cycle to a given instant.

Pitch.—An acoustic term describing the frequency of a tone.

Plate.—The positive electrode in a vacuum tube.

Potential.—Electrical pressure which determines the flow of current through a given resistance or impedance. The term *pressure* or *voltage* should be used rather than *potential*.

Potentiometer.—A high resistance (200 to 300 ohms) usually connected across the A battery and having a sliding contact making it possible to provide a fine adjustment of the plate voltage. Sometimes it is connected in a manner to provide adjustment of voltage between grid and filament. Sometimes called a stabilizer. In electrical engineering the definition of a potentiometer is entirely different.

Primary.—The first winding of a transformer or the winding on which current is impressed.

Radio frequency.—The term applied to currents pulsating at a frequency too high to be heard by the human ear. Used to identify the currents in the antenna circuit.

Reactance.—That part of the total impedance which is due to capacity and inductance.

Reactance coil.—A coil whose reactance is large compared to its resistance.

Rectifier.—A device which converts alternating current into direct or pulsating current.

Reflex Circuit.—One in which the amplifier tubes are made to function as both radio and audio-frequency amplifiers simultaneously.

Regeneration.—Increasing amplification in a vacuum tube by returning part of the output to the grid to be re-amplified.

Regenerative Receiving Set.—A set in which an electron tube is so connected that part of the plate circuit power is fed back to the grid circuit (by a tickler or through the tube capacity), thus building up great amplification.

Relay.—An electro-magnetic switch by means of which a local power circuit is controlled.

Resistance.—That part of the total impedance which is due to dissipation of energy in the circuit.

Resonance.—Condition of a radio circuit when it gives maximum response to an impressed wave or voltage. When a circuit is in resonance it is also said to be tuned.

Resonance Transformer.—Any loose coupled tuning inductance having a primary and secondary each with a variable condenser in the circuit. Tuning the secondary circuit brings it in resonance with the primary, thus enabling signals to be heard with greatest volume.

Rheostat.—A variable resistance used to control the filament lighting current of detector and amplifier tubes.

Secondary.—The second winding of a transformer or the winding which delivers energy.

Shunt.—A by-pass or an instrument connected in parallel with another.

Signal.—Any electrical current conveying a message.

Single-circuit Receiving Set.—A set in which the detector is connected to a coil or other circuit element in the aerial circuit.

Soft Tube.—An electron tube suitable for use as a detector but unsuited for use as an amplifier because of the characteristics developed by the residual air. Sometimes called a gas tube.

Spark Transmission.—The transmission of radio messages by damped waves produced by a spark transmitting set.

Static.—Electric disturbances due to atmospheric discharges.

Super-audible.—A frequency which lies above the audible range.

Super-heterodyne.—Use of a heterodyne to produce an intermediate frequency lower than that of the wave frequency, the intermediate frequency being in turn detected as in ordinary reception.

Super-regeneration.—A method of amplifying in which self oscillations are prevented by periodically damping the circuit.

Thermionic Emission.—The emission of a stream of negative electrons from a heated filament (cathode) in a vacuum tube.

Three-electrode Tube.—Same as electron tube.

Tickler.—A coil used to inductively feed back power from plate circuit to grid circuit in a regenerative receiving set.

Tikker.—A type of interrupter used to detect C. W. signals.

Tuning Coil.—A coil of wire for carrying the inductance (and hence the resonance wave lengths) of a circuit. Provision is made so that various numbers of turns can be connected in circuit. When used in an antenna circuit a tuning coil is also a loading coil.

Tuner.—The portion of a circuit in which tuning is done.

Two-circuit Receiving Set.—A set in which the detector is connected to a secondary circuit coupled to the aerial circuit.

Undamped waves.—Continuous waves.

Vacuum Tube.—An evacuated bulb, or one containing a rare gas and having two or more elements.

Variable Condenser.—A condenser the capacity of which can be readily varied. In its usual form it is two sets of plates which interleave but do not touch each other, one set being rotatable.

Vernier.—A term applied to condensers, rheostats, etc., having a means for providing a finer adjustment than is possible with similar apparatus not so equipped. Applied also to a variable condenser having only 3 or 5 plates.

Vibration.—Rapid to and fro motion.

Volt.—Unit of electric pressure.

Volt meter.—Instrument for measuring electric pressure.

Wave meter.—An instrument for measuring wave frequency (or wave length).

Wave Length.—The distance between successive crests of a radio wave as it passes along on its way between transmitting and receiving stations. Wave length is inversely proportional to wave frequency.

Wave Trap.—A resonant circuit used to eliminate an interfering signal.

Aerial		Frequency Meter (Wavemeter)	
Ammeter		Galvanometer	
Arc		Glow Lamp	
Battery (the positive electrode is indicated by long line)		Ground	
Coil Antenna		Inductor	
Condenser, Fixed		Inductor, Adjustable	
Condenser, Fixed, Shielded		Inductor, Iron Core	
Condenser, Variable		Inductor, Variable	
Condenser, Variable (with moving plate indicated)		Jack	
Condenser, Variable Shielded		Key	
Counterpoise		Lightning Arrester	
Crystal Detector		Loud Speaker	

FIGS. 7,183 to 7,216a.—Chart showing various symbols used in radio diagrams.

Microphone (Telephone Transmitter)



Photo electric Cell



Piezoelectric Plate



Resistor



Resistor, Adjustable



Resistor, Variable



Spark Gap, Rotary



Spark Gap, Plain



Spark Gap, Quenched



Telephone Receiver



Transformer, Air Core



Transformer, Iron Core



Transformer, with Variable Coupling



Voltmeter



Wires, Joined



Wires, Crossed, not Joined



Diode (or half-wave rectifier)



Triode (with directly heated cathode)



Triode (with indirectly heated cathode)



Screen Grid Tube (with directly heated cathode)



Screen Grid Tube (with indirectly heated cathode)



Rectifier Tube, Full-Wave (Filamentless)



Rectifier Tube, Full-Wave (with directly heated cathode)



Rectifier Tube, Half-Wave (Filamentless)



INTERNATIONAL MORSE CODE AND CONVENTIONAL SIGNALS

TO BE USED FOR ALL GENERAL PUBLIC SERVICE RADIO COMMUNICATION

1. A dash is equal to three dots. 3. The space between two letters is equal to three dots.
2. The space between parts of the same letter is equal to one dot. 4. The space between two words is equal to five dots.

A	• —
B	• — • — • —
C	• — • — • — • —
D	• — • — • —
E	•
F	• — • — • —
G	• — • — • —
H	• — • — • —
I	• •
J	• — • — • — • —
K	• — • — • —
L	• — • — • —
M	• — • —
N	• — • —
O	• — • — • —
P	• — • — • — • —
Q	• — • — • — • —
R	• — • — • —
S	• • • —
T	• — • —
U	• — • — • —
V	• — • — • — • —
W	• — • — • — • —
X	• — • — • — • —
Y	• — • — • — • —
Z	• — • — • — • —
Ä (German)	• — • — • — • —
Å or Ä (Spanish-Scandinavian)	• — • — • — • —
CH (German-Spanish)	• — • — • — • —
É (French)	• — • — • — • —
Ñ (Spanish)	• — • — • — • —
Ö (German)	• — • — • — • —
Ü (German)	• — • — • — • —
1	• — • — • — • —
2	• — • — • — • —
3	• — • — • — • —
4	• — • — • — • —
5	• — • — • — • —
6	• — • — • — • —
7	• — • — • — • —
8	• — • — • — • —
9	• — • — • — • —
0	• — • — • — • —

Period	• • • • •
Semicolon	• — • — • — • —
Comma	• — • — • — • —
Colon	• — • — • — • —
Interrogation	• — • — • — • —
Exclamation point	• — • — • — • —
Apostrophe	• — • — • — • —
Hyphen	• — • — • — • —
Bar indicating fraction	• — • — • — • —
Parenthesis	• — • — • — • —
Inverted commas	• — • — • — • —
Underline	• — • — • — • —
Double dash	• — • — • — • —
Distress Call	• • • — • — • — • — • —
Attention call to precede every transmission	• — • — • — • —
General inquiry call	• — • — • — • —
From (de)	• — • — • —
Invitation to transmit (go ahead)	• — • — • —
Warning—high power	• — • — • — • —
Question (please repeat after)—interrupting long messages	• — • — • — • —
Wait	• — • — • —
Break (Bk.) (double dash)	• — • — • — • —
Understand	• — • — • — • —
Error	• — • — • — • —
Received (O. K.)	• — • — • —
Position report ^a (to precede all position messages)	• — • — • — • —
End of each message (cross)	• — • — • — • —
Transmission finished (end of work) (conclusion of correspondence)	• — • — • — • —

Watt.—Unit of power. Voltage multiplied by amperage.

Wired Radio.—Application of the principles of radio to communication over wires.

Essentials of Radio Communication.—Although there is a great multiplicity of “radio sets,” the performance of a number of these consists of just four functions known as:

1. Reception;
2. Selection;
3. Detection;
4. Audition.

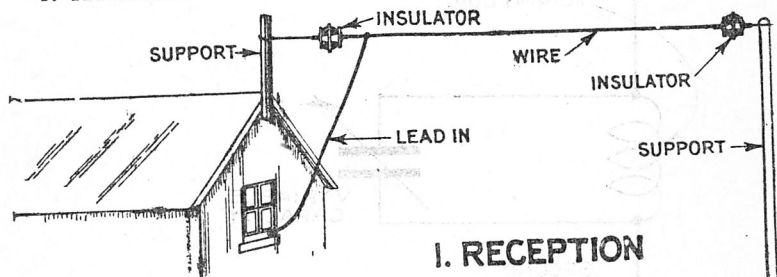


FIG. 7,217.—Aerial for reception of the radio waves.

and in those sets of greater refinement there is an additional function known as:

5. Amplification.

Reception.—The aerial is that part of the radio apparatus which receives or “catches” the radio waves and leads them to the selection part of the set. A typical aerial is shown in fig. 7,217.

Selection.—When several transmitting stations are broadcasting at the same time it is necessary to provide means for

cutting out or making the apparatus non-responsive to all stations except the one it is desired to hear. This function is called *selection* and is accomplished by a process called *tuning*.

It is found that in a circuit containing *inductance* and *capacity*, certain combinations of these give much greater response than others to a given wave length. Hence, if each broadcasting station have a different wave length, the receiving set can be tuned to respond to any selected station by adjusting the relative amounts of inductance and capacity.

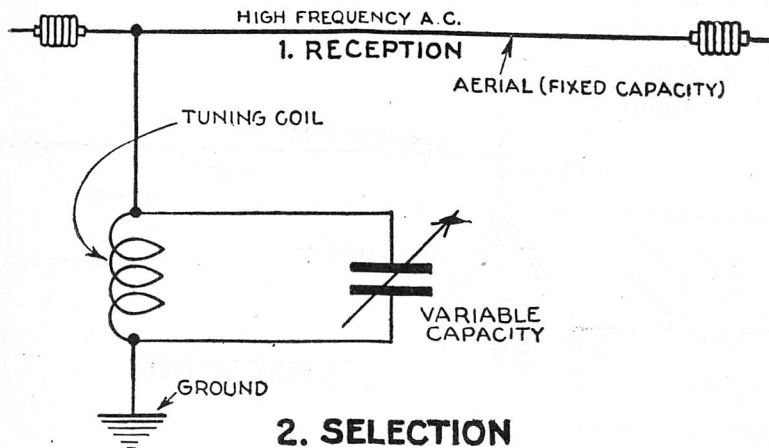


FIG. 7,218.—Aerial and tuning coil, which provide a fixed capacity and variable inductance, the essential elements in the simplest form of circuit necessary for tuning.

When the strength of the signals from the selected station is greatest, the circuit is in tune or in *resonance* with the incoming wave length, or frequency, and then only a very small impulse is required to start large current in the circuit.

In the simplest form of set the inductance is varied by means of a tuning coil and variable condenser, so that any amount of inductance relative to the capacity of the aerial may be obtained to tune to a given wave length as shown in fig. 7,218.

Detection.—This third essential function consists in *converting the alternating current in the aerial and inductance coil into a*

pulsating uni-directional current so as to make the transmitted signals audible in the telephone receiver.

The part of the apparatus that converts the current is called a detector.

A detector is essential because the human ear is not responsive to vibrations above a few thousand per second. The detector changes the high

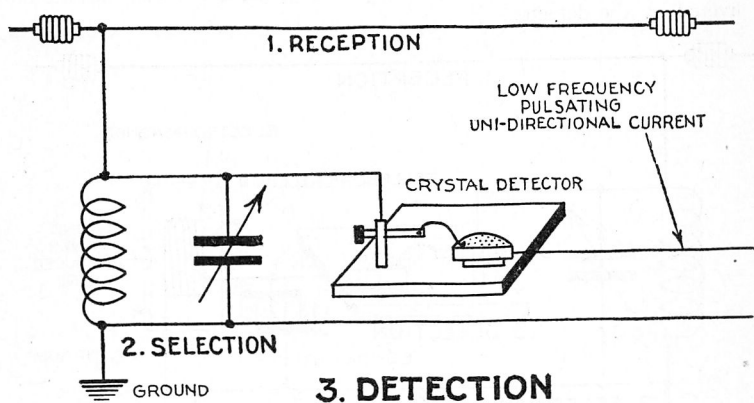


FIG. 7,219.—Addition of crystal detector to the single circuit of fig. 7,218, the essential element necessary for *detection*.

frequency currents to impulses traveling in one direction in the circuit to the number of 100 to a few thousand per second. The simplest form of detector is known as the *crystal detector*. Galena, silicon, and carborundum are the names of three of the crystals used.

The purpose of the head receivers is to change the impulses of direct (one way travel) current to sound waves which can be heard.

The essential elements of the simplest circuit for reception, selection and *detection* are shown in fig. 7,219.

Audition.—The high frequency impulses having been rectified and reduced to audible limits by the detector it is only necessary to add telephone head receivers to change these impulses to sound waves so they can be heard.

Fig. 7,220 shows this addition to the set, for simplicity a single receiver being shown. The latter it will be seen consists essentially of an electro-magnet and a sensitive diaphragm which vibrates to produce sound waves as influenced by the low frequency pulsating uni-directional current delivered by the detector.

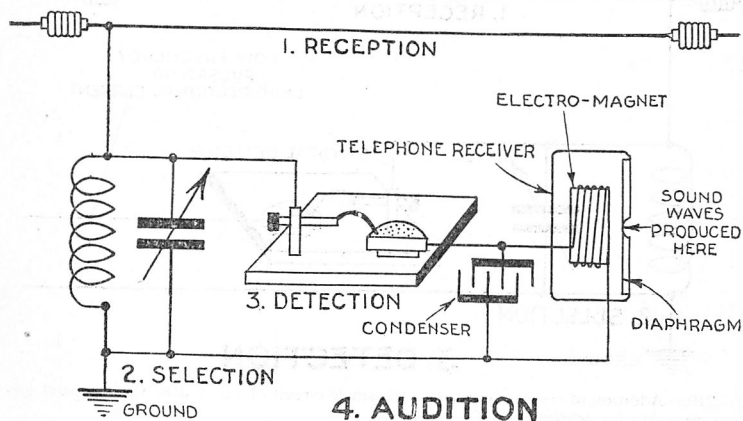


FIG. 7,220.—Addition of telephone receiver with condenser to the simple circuit of fig. 7,219, the essential element for *audition*.

The receiver is assisted in converting the pulsating uni-directional current coming from the detector by a condenser placed in circuit as shown. This condenser alternately receives and gives up charges, responsive to the state of the pulsating uni-directional current. Fig. 7,221 shows a crystal detector set as actually constructed for the four functions indicated in fig. 7,220, except that fig. 7,221 shows a *variable* inductance coil.

Summary

(Operation of simple crystal detector set shown in fig. 7,221.)

Aerial.—Converts radio waves into an alternating current of high frequency.

Inductance Coil.—Forms, together with the aerial, a circuit which can be tuned to respond to the incoming radio wave. In this set it alone constitutes the “tuner.”

Crystal Detector.—Converts the alternating current in the aerial into a pulsating uni-directional current.

Telephone Receivers.—Convert the pulsating uni-directional current into sound.

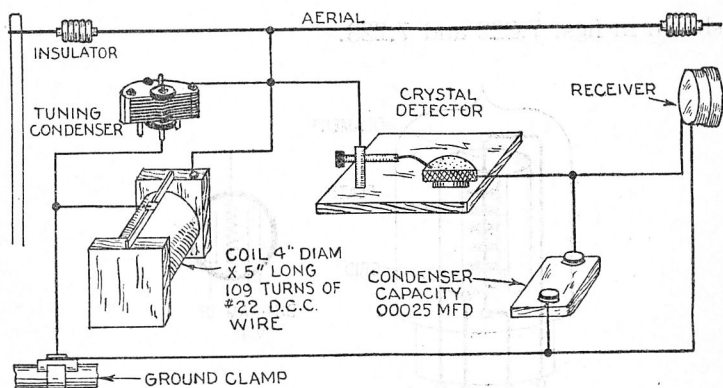


FIG. 7,221.—Small crystal detector set as actually constructed corresponding to the elementary set shown in fig. 7,220, with exception of a variable instead of a fixed inductance coil.

Amplification.—The word amplify means *to increase or enlarge*; in radio, amplification is the act or process of strengthening the radio signals, so that the more distant stations can be heard, and the sound augmented. The simplest set possessing amplification is the tuning coil set and a *vacuum tube* detector.

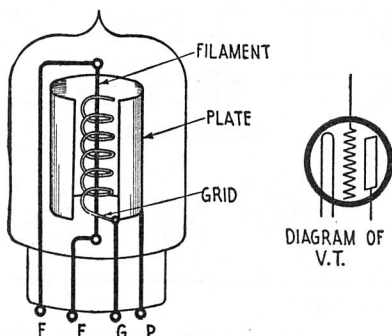
To understand the working of this set, the principles of the tube should be first considered.

Vacuum Tube Detector.—This device was first brought out by Dr. Lee de Forest under the trade name *Audion*. It is one of the most sensitive instruments known to science yet it does not require more than an elementary knowledge to use it in radio reception. In its simple form it consists of a glass

bulb, similar in shape to an electric lamp, evacuated to a high degree and containing three elements:

1. Filament;
2. Plate;
3. Grid.

as shown in figs. 7,222 and 7,223.



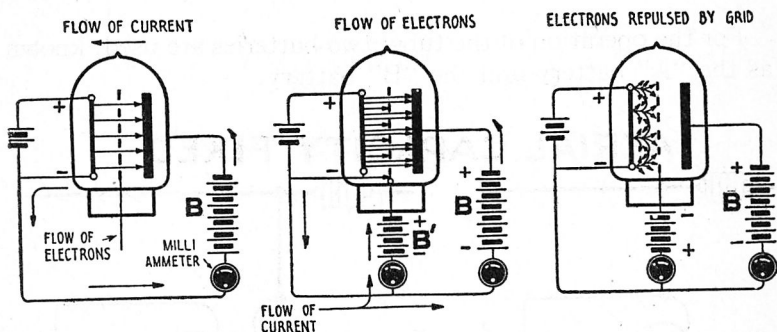
FIGS. 7,222 and 7,223.—View of vacuum tube showing elements and diagram of same.

The filament is a piece of high resistance wire which is heated, by current, to brilliancy, as in an electric lamp. When this filament is heated it throws off millions of little electrical units known as negative ions. Around the filament is constructed a small sheet of metal (the plate) to which the ions can go, and so return to the circuit. Ions can travel only from the hot filament to the comparatively cold plate and cannot reverse and go the other way. It is this property which is utilized when employing the vacuum tube as a detector for changing the radio waves of vibrating current into direct current impulses. It is necessary to have some means of controlling the number of ions which reach the plate and for this the "grid" is inserted.

The grid consists of a closely wound spiral or finely woven screen of wire surrounding the filament and through which the ions must pass to reach the plate. Interposed in the path from filament to plate, any electrical charge put upon it from the aerial circuit will either increase or decrease the ions reaching the plate and so vary the current through the head receivers.

The vacuum tube is used in radio for four purposes.

1. As a detector of received radio currents. (Instead of a crystal detector.)



FIGS. 7,224 to 7,226.—Diagrams illustrating the operation of the three element vacuum tube. A plate filament circuit is secured by the electrons traveling *from the filament to the plate*, since they are attracted by the plate *positively* charged, although the current from the battery B, is arbitrarily said to flow in this circuit *from the plate to the filament*. If the grid be connected as shown above in fig. 7,225, including in this circuit a battery and a milli-ammeter, a current will flow in the grid circuit because a certain number of electrons are stopped by the positively charged grid which allows the current of the battery B' to flow in the grid filament circuit. Now if the polarity of the grid be changed as in fig. 7,226, the flow of electrons from the filament, when the grid is negative is repulsed, for in this case the electrons are negatively charged. Accordingly, the current from the plate, having no path, is suddenly stopped. Evidently then the grid acts as an automatic interrupter.

2. As an amplifier of received currents. (For greatly increasing the loudness of signals received.)
3. As a generator of alternating currents. (For radio telephony and telegraphy.)

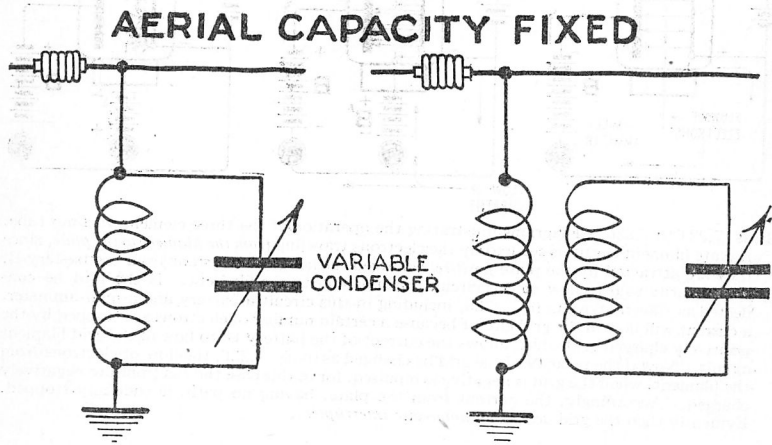
The tube acts as a detector on account of its rectifying action; that is, the incoming high frequency alternating current is rectified or changed to a uni-directional current, one half of the alternating (the positive side) being permitted to pass through to the filament circuit, thence to the phones.

The natural amplifying property of the tube is that when properly connected, it will add current from a battery connected in one of the circuits to the signals, making them much louder when passed through head receivers or a loud speaker.

4. As a transmitter,

Direct current is converted into high frequency alternating current using large tubes to change 350, 500, 1,000 or 2,000 volt *d.c.* to *a.c.* of frequency of 50,000 to 2,000,000, per second.

For the operation of the tube, two batteries are used, known as the "A" battery and the "B" battery.



Figs. 7,227 and 7,228.—*Tuning methods 1. Aerial capacity fixed.* Fig. 7,227, variable condenser fixed inductance coil; fig. 7,228, variable condenser with inductive coupling.

It should be noted that the amount of B battery voltage applied to the plate of the tube determines whether the tube will operate simply as a detector, or as an amplifier in addition to its function as detector.

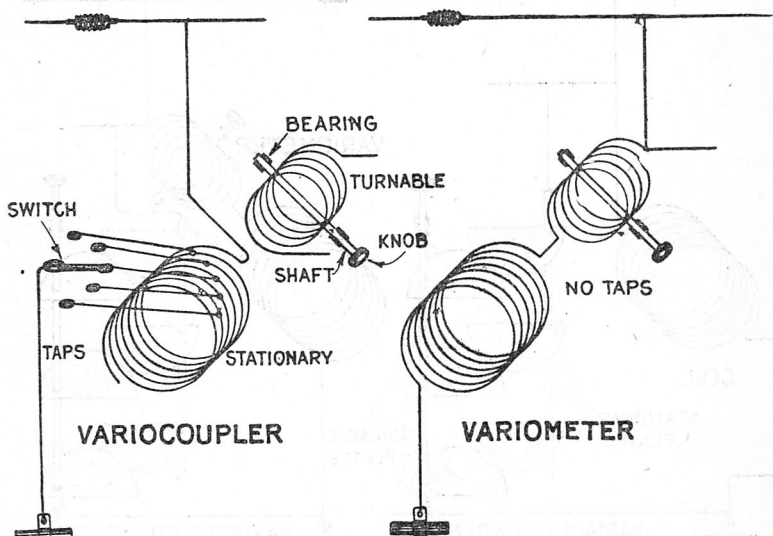
The A battery is used to heat the filament of the vacuum tube, the amount of current drawn from the battery being controlled by a rheostat which serves to bring the filament to the proper temperature for best results; usually a 6 volt storage battery is used.

The B battery furnishes the local energy which amplifies the receiving signals so as to increase the loudness of tone produced in the head receivers or loud speaker. It is connected through the proper terminal to the plate circuit to create a difference of voltage between the filament and the plate.

Methods of Selection.—In the simple circuits thus far shown, tuning the apparatus so that it will respond to the desired wave length is accomplished by having the capacity (that of the aerial) fixed and varying the inductance by means of a single slider tuning coil.

Selection may be accomplished in numerous other ways. The following methods (although some are old) should be noted.

CAPACITY FIXED



FIGS. 7,229 and 7,230.—*Tuning methods 2. Capacity fixed.* Fig. 7,229, variocoupler mutual induction principle; fig. 7,230, variometer, combination of self-induction and mutual induction principles. These are old methods but show principles.

1. Capacity fixed, variable inductance.

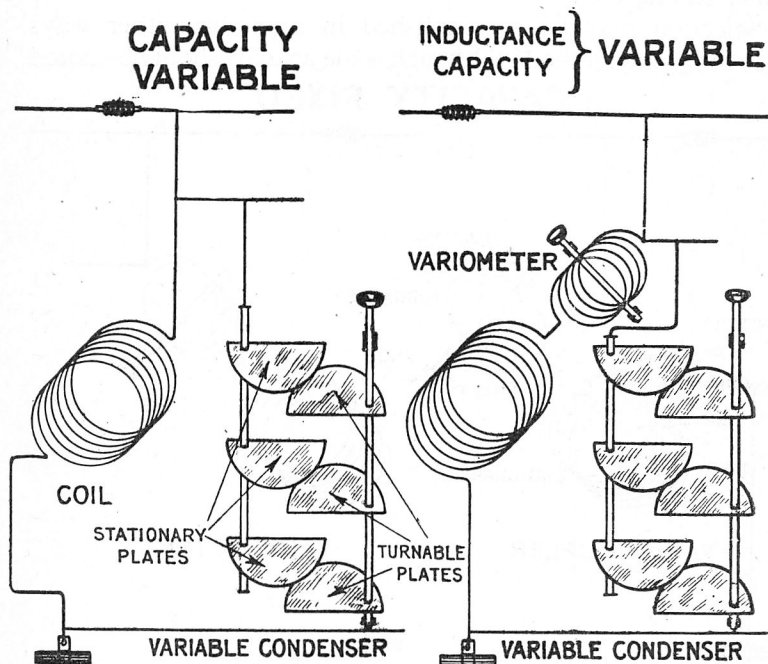
- | | |
|----------------------------|------------------|
| a. One slider tuning coil; | c. Variocoupler; |
| b. Two slider tuning coil; | d. Variometer. |

2. Capacity variable, inductance fixed.

3. Capacity and inductance variable.

These various methods are shown in figs. 7,229 to 7,232.

Using a single slide tuner, as in fig. 7,221, will not give tuning sharp enough to cut out serious interference. The efficiency is increased by using two slides. The coil of fig. 7,221 is a primary induction coil (single coil) and it works on the principle of self-induction. It works on the



FIGS. 7,231 and 7,232.—*Tuning methods 3.* Fig. 7,231, capacity variable by use of variable condenser, fixed inductance; fig. 7,232, both inductance and capacity variable.

principle of self-induction as distinguished from a secondary induction coil which consists of two coils with no metal connection between, working on the principle of mutual induction; that is, use is made of the magnetic field set up to transfer the energy from one coil to the other.

The variocoupler (fig. 7,229) is an example of this method. Here tuning is accomplished by cutting out various sections of one coil and by adjusting the angular position of the second coil.

A modification of this method is the variometer (fig. 7,230) in which there are no taps, but the coils are connected together at one end as shown.

For a small wave length range a variometer can be used with connection similar to that of a single slide tuner. With the addition of a condenser and large size variometer a very considerable range of wave length can be covered. In fig. 7,231, the tuning is done by varying the capacity and in fig. 7,232, by varying both inductance and capacity.

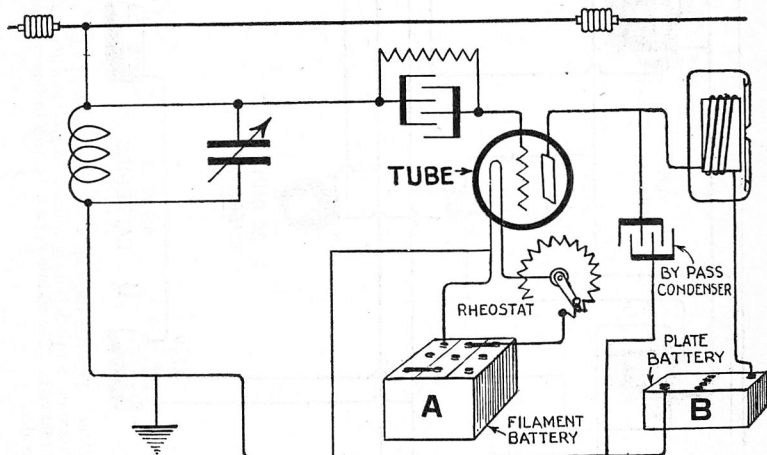


FIG. 7,233.—Simple one tube set in which the tube acts as detector and amplifier. In series with the grid element of the tube and aerial is a grid leak condenser, comprising a condenser and a high resistance in parallel as shown. The effect of this grid condenser is to render the tube a very sensitive detector. A rheostat is placed in the A, or filament battery circuit to adjust the filament current to its proper value which depends on the type of tube used. The by-pass condenser is shunted across the phone and B battery to furnish a low impedance path for the high frequency output current of the detector around the phone and B or plate battery.

Amplification with Tube Detector.—The simplest set possessing amplification is the combination of the tube and tuning coil as shown in fig. 7,233. By using another tube or several additional tubes this amplification may be carried still further, for it is merely necessary to feed the output of one tube into the grid of the next tube.

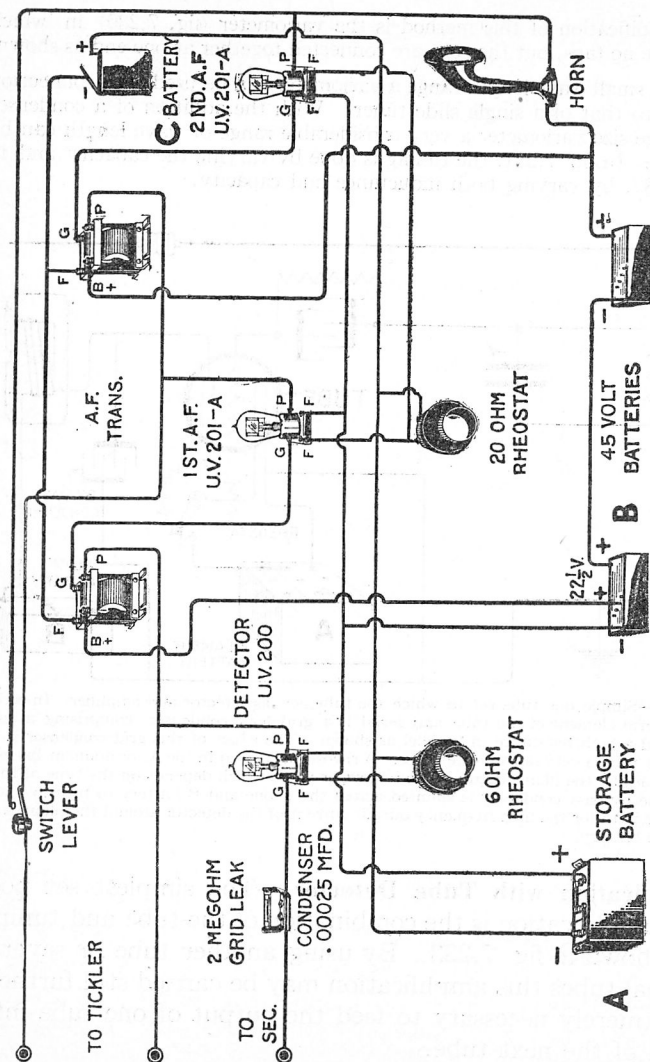


FIG. 7,234.—Two stage audio frequency amplifier. This two stage amplifier can be added to any single tube set. Instead of using jacks to plug in different stages of amplification, a switch is used instead. A good amplifier tube such as the UV-201A should be used and plate voltage should be about 90 volts. The addition of a C battery in this amplifier will tend to eliminate distortion so that reception will be clearer and louder.

In this way the incoming radio wave may be repeated and built up until the amplification may be as high as 50,000,000; that is, the characteristics of the incoming wave may be reproduced by an exactly similar wave of enormously greater magnitude.

Coupling of Amplifiers.—If more than one amplifier be used some apparatus must be interposed between successive tubes to obtain the maximum power output of the lower tube and if possible, at the same time obtain the maximum voltage

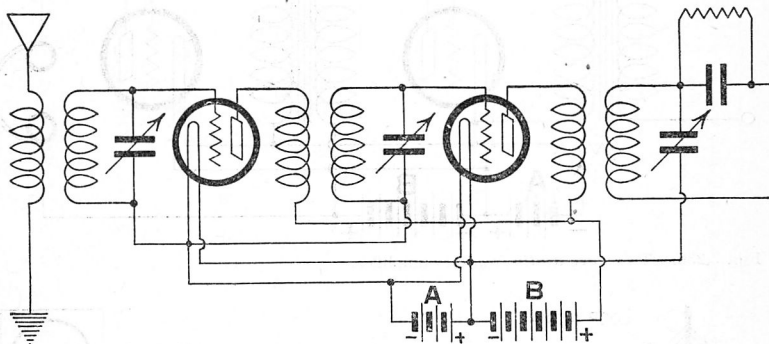


FIG. 7,235—Two stage radio frequency amplifier. Radio frequency amplifiers are used ahead of the detector on receiving sets. In order to prevent distortion in the case of weak signals several stages of amplification are used; some of these stages should be *r.f.* and some *a.f.*

charges on the grid of the upper tube. This is generally done by a transformer coupling. Fig. 7,234 shows connection for two stage amplification.

Radio Frequency Amplification.—By definition radio frequency amplification is *the amplification of the high frequency variations of voltage in the aerial circuit before reaching the detector tube.* These high frequencies are known as radio frequencies and vary from 20,000 to 300,000,000 cycles per second. Fig.

7,235 is a circuit diagram showing a two stage radio frequency amplifier hook up.

Audio Frequency Amplification.—By definition audio frequency amplification is *the amplification of the low frequency pulsations leaving the detector tube before being fed to the loud speaker*. Fig. 7,236 shows a two stage audio frequency amplifier hook up.

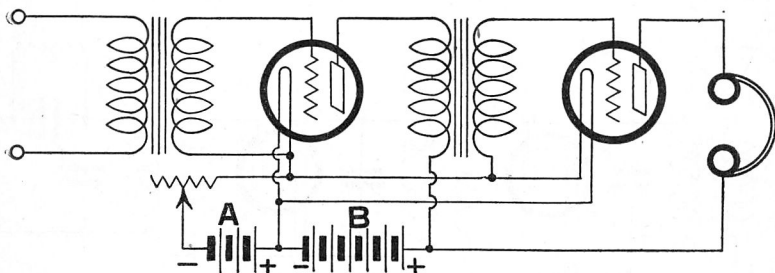


FIG. 7,236.—Two stage *audio frequency* amplifier.

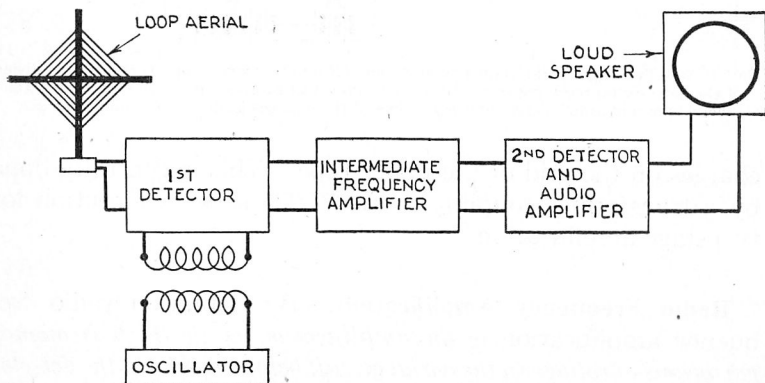


FIG. 7,237.—General arrangement of super-heterodyne set showing placement of *intermediate frequency* amplifier.

Intermediate Frequency Amplification.—By definition intermediate frequency amplification is *the amplification of the intermediate frequency pulsations*, or, frequencies from 20,000 to about 75,000 cycles per second.

Amplification at these frequencies is used in super-heterodyne receivers, the amplifier usually consisting of a *r.f.* amplifier using transformer coupling, the transformer being designed to cover very high wave lengths. An intermediate frequency amplifier hook-up is shown in fig. 7,237.

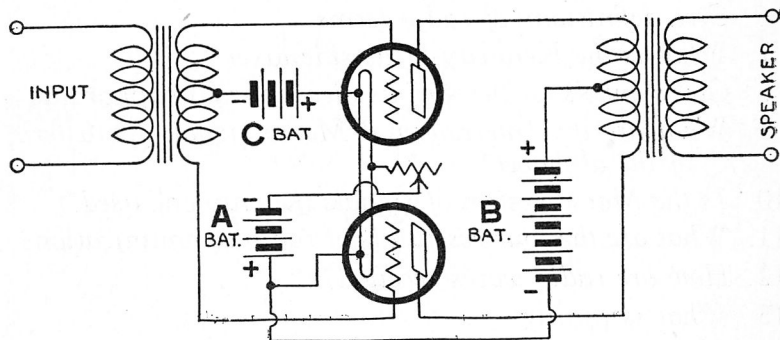


FIG. 7,238—Push pull amplification circuit. This method of amplification requires two tubes of the same type in each stage. The grids of the tubes are not connected together, as is the case in parallel operation, but are connected to opposite ends of a mid tapped transformer secondary. The mid tap is used as a common connection for making connection to the negative *bias* voltage of the grids. The grid voltage varies due to the impressed alternating voltage, which causes the grid to be alternately more and less negative. In push pull operation the grid of one tube is most negative when the grid of the other tube is least negative; therefore, as the plate current of one tube increases the plate current of the other tube decreases. To describe this action the word *push pull* was coined. The action is similar to the operation of a hand car, where one operator pushes on the cross bar as the other pulls, and vice versa. A push pull parallel stage is one in which two or more of push pull circuits are used in parallel.

Push-Pull Amplification.—By definition push-pull amplification is *a method of generating more power for the loud speaker than usually obtained by audio amplifiers*. In the last stage two tubes are thus employed and so connected as shown in fig. 7,238 that they are used alternately on the two halves of each *a.f.* cycle.

TEST QUESTIONS

1. What is Dr. Einstein's theory of the ether?
2. What happens when a stone is thrown into a pond?
3. What does Marconi say about radio waves?
4. Compare radio waves with water waves.
5. Draw diagram illustrating resonance.
6. Give definitions of radio terms.
7. What is the Kennelly-Heaviside layer?
8. Give symbols for the various pieces of radio apparatus.
9. What are the International Morse signals for letters of the alphabet?
10. Is the Morse system of signals the only one used?
11. What are the four essentials of radio communication?
12. How are radio waves received?
13. What is tuning?
14. How are radio signals made audible in the telephone receivers?
15. Explain audition in detail.
16. What is a vacuum tube?
17. How does a vacuum tube work?
18. Name three uses made of vacuum tubes in radio.
19. Explain use of A battery and B battery.
20. Explain the different methods of tuning.
21. How is amplification obtained with tube detector?
22. Draw a diagram showing two stage audio frequency amplifier circuit.
23. Explain the coupling of amplifiers.

CHAPTER 175

Vacuum Tubes

The name *vacuum tube*, which is descriptive of the fact that a high vacuum is required for operation, is widely used in America to designate what in England is familiarly known as a *valve*, a term which is roughly descriptive of the operation of the tube. There are a great many different types of vacuum

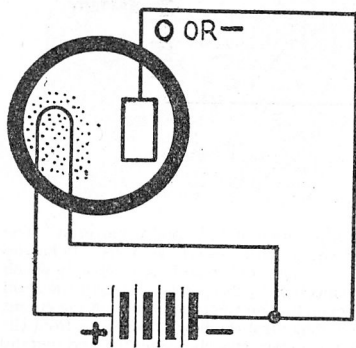


FIG. 7,239.—How a tube works 1. Electrons are thrown off by a heated filament. If no means be provided for drawing the emitted electrons away from the filament, they will fall back as rapidly as they are emitted and the space surrounding the filament will be filled with a constant number of electrons.

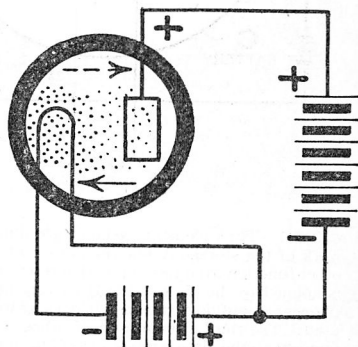


FIG. 7,240.—How a tube works 2. If d.c. voltage were applied to plate making plate + with respect to the filament, electrons would be attracted to the plate and a current would be set up as shown. The diagram shows the current flowing from plate to filament in the tube, while the electrons flow from the filament to the plate.

NOTE.—How a tube works 3. If either the temperature of the filament, or the voltage on the plate be varied, the flow of current will vary, but it will always flow in the same direction.

tubes or valves, each of which has its own particular trade name, and they may be classified:

1. With respect to communication, as

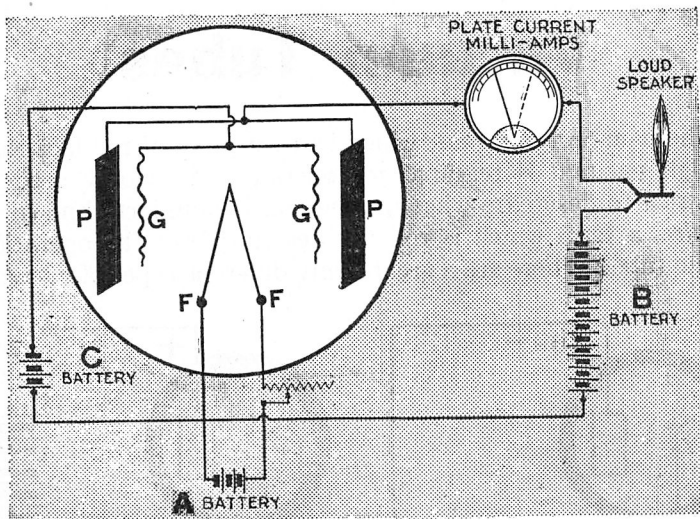


FIG. 7,241—Three element vacuum tube illustrating application of A, B, and C batteries. The work of the storage A battery is to heat the filament which gives off electrons. It has no other function in connection with a receiving set. The source of the positive electricity which is applied to the plate is the B battery and its connection to the plate is through the head phones, amplifying transformer or loud speaker, depending on the type of amplifying circuit used. The third element or grid, whose function is to control the flow of electrons from the filament to the plate, employs the C battery which puts a negative charge on the grid thereby acting as a governor to retard or accelerate the flow of electrons from the filament to the plate.

- a. Transmitting;
- b. Receiving.

2. With respect to the current, as

- a. Direct { dry cell
storage battery
- b. Alternating.

3. With respect to its use in the circuit, as

- a. Rectifier;
- b. Detector;
- c. Amplifier;
- d. Ballast.

4. With respect to the number of elements, as

- a. Two;

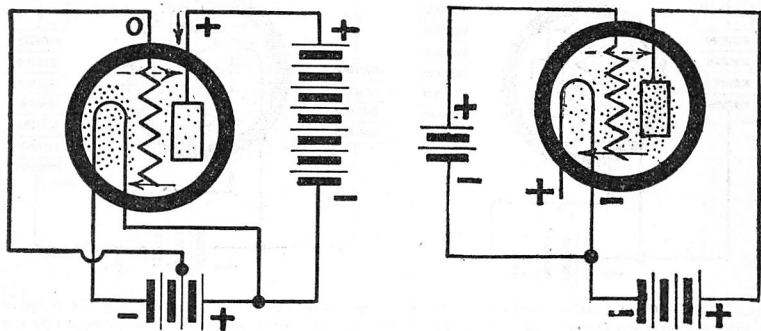


FIG. 7,242.—How a tube works 4. Electron flow can be controlled by a grid. If the grid be connected to the filament battery at a point half way between the filament connections as shown, so that the average difference of voltage between the grid and filament is zero, no change in the plate current will be noticed.

FIG. 7,243.—How a tube works 5. If the grid be kept positive with respect to the filament, the grid would aid the plate in drawing the electrons away from the filament. Since the grid is much closer to the filament than to the plate, its effect on the electron flow is relatively greater than that of the plate.

- b. Three;
- c. Four (screen grid);
- d. Five.

Electrons.—By definition an electron is *the smallest charge of negative electricity known*. When any substance is heated to

incandescence in a vacuum, it throws off into the space surrounding it vast quantities of electrons—invisible small particles of negative electricity.

Some substances throw off electrons much more readily than others, and the hotter the substance the greater is the number of electrons emitted. The reason for this is that all matter is largely composed of these particles of negative electricity, which are always in rapid and violent motion. The increase of temperature increases the speed and violence of their motion.

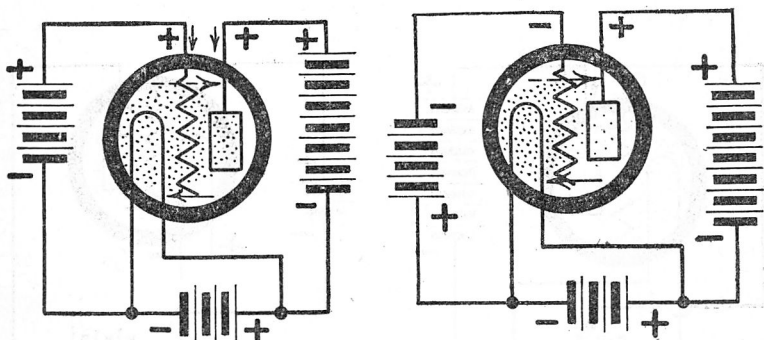


FIG. 7,244.—*How a tube works 6.* Many of the electrons which are speeded up by the positive grid will pass between the grid wires and go to the plate, but some of them will be collected by the grid and establish a current in the grid circuit.

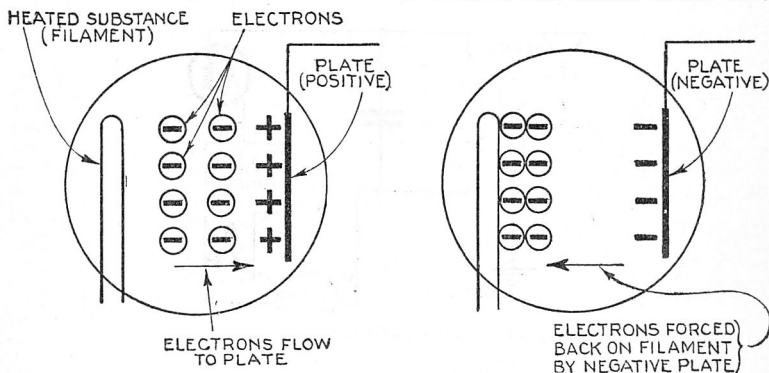
FIG. 7,245.—*How a tube works 7.* If the grid be kept negative with respect to the filament no current will flow in the grid circuit, and the plate current will be reduced due to action of the grid in forcing some of the electrons back to the filament, as shown.

There is always an attractive force between electrons and the substance, but when they attain a high speed, some of them overcome the attractive force and are "bumped off" only to return again unless some outside force carries them away.

Electron and Current Flow.—If a plate be placed in a tube and kept positive with respect to the filament the electrons leaving the filament and attracted by the positive plate will flow from the filament to the plate as in fig. 7,246.

Again if the plate be kept negative with respect to the filament the electrons which tend to leave the filament will be held against it by the repulsion due to like negative charges as in fig. 7,247.

In the first instance, as stated, electrons flow from a heated substance to a positive plate. This direction of flow is contrary to the usual conception of the direction of flow of electricity, which is considered to be from positive to negative. The reason for this is that before the discovery of electrons, experimenters decided to consider that current flowed from



FIGS. 7,246 and 7,247.—Vacuum tube diagrams illustrating electron flow.

positive to negative as a sort of arbitrary rule. This rule has continued in use even though later experiments seemed to prove the contrary to be true. Therefore, current is always considered to flow from positive to negative, although the electrons actually travel in the opposite direction, as in fig. 7,246.

NOTE.—Space charge. According to Prof. Taylor, if the space between filament and plate were to be filled with electrons, similar to the droplets of water in a cloud, then this charge would be called a *space charge*. At any point in space in the vicinity of a negative charge the electric field is such that it tends to repel another negative charge. Thus it is seen that between the filament and plate there is an electric field due to the plate tending to pull electrons to it, while at the same time there is another electric field repelling the electrons away from the plate, due to the space charge. As a result of the repelling action of the field caused by the space charge it is evident that the resultant electric field intensity is less than that produced by the B battery alone, in the space between filament and plate. From the lessened field strength it follows that fewer electrons will move from filament to plate during each second, and consequently smaller current will flow because of it. In general, it can be stated that anything which reduces the intensity of the electric field in any region of space will decrease the current through that space.



FIG. 7,248.—Two element tube consisting of filament and plate.

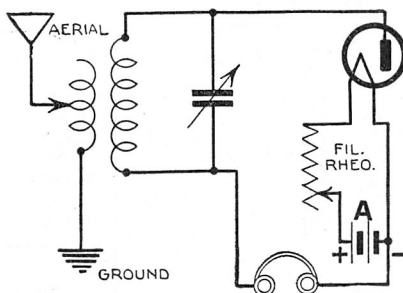


FIG. 7,249.—Two element vacuum tube used as detector.

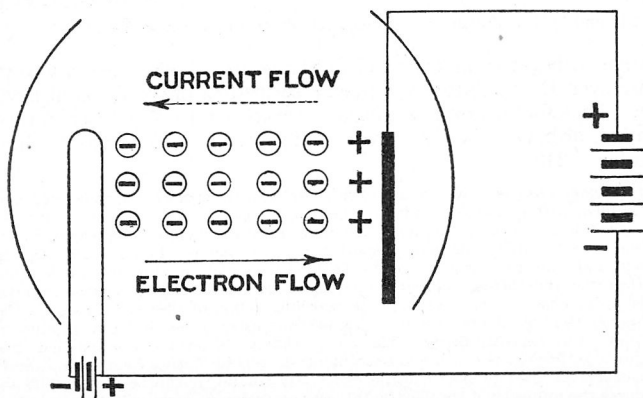
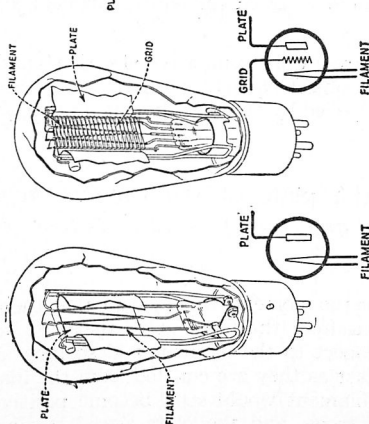
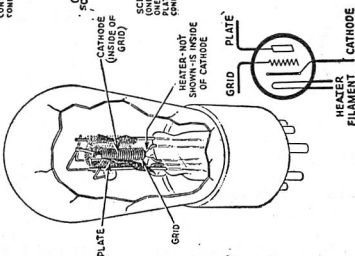
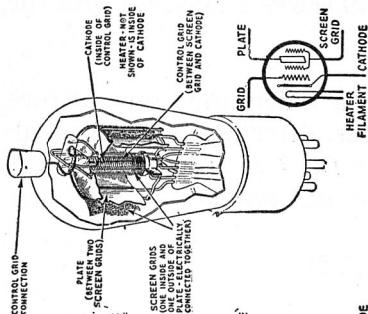


FIG. 7,250.—Vacuum tube diagram illustrating electron and current flow.

NOTE.—Assume a microscopic eye and see what is happening within the radio tube as the filament temperature rises. Electrons will be seen coming out of the filament and moving away from it, in the direction of the plate. In fact, it is probable the appearance of the electrons would be similar to a cloud of water vapor formed in a valley between two high hills. As the



Figs. 7,251 to 7,254.—Views of two, three, four and five element vacuum tubes.
Figs. 7,255 to 7,258.—Diagrams of two, three, four and five element vacuum tubes.

rays of the setting sun ceased to strike the valley, the earth would tend to cool by the process of radiation. As a consequence of this cooling of the earth and air above it, moisture would condense in the form of fog. As time went on into the evening more cooling would take place and more fog would form. After sufficient time the fog would fill the valley and perhaps reach the top of the surrounding hills. In a very similar way the microscopic eye would see a cloud of electrons first form around the filament). However, in a very short time this cloud would expand until it reaches and surrounds the plate. Now since the plate is in a region surrounded by electrons the voltage of the plate would necessarily be low. In fact, it would be lower than the voltage of the filament. As the temperature of the filament became constant, a cloud of electrons would be seen filling the tube, also coming out of the filament with the simultaneous disappearance of others as they condensed into the filament again. At this state let the temperature of the filament be raised and again observe what takes place. If this be done, what might be called an explosion of electrons from the filament will be observed. With an increase in filament temperature more electrons will probably be present when equilibrium attains than at the lower temperature. This condition is similar to the case where the temperature of a liquid is raised with the saturated vapor in contact with it. As a result of the increased temperature of the liquid the vapor density also increases.

Two Element Tube.—Formerly the two element tube was used as a detector, but now it is employed chiefly as a rectifier in power supply units. Fig. 7,249 shows a hook up with the tube used as a detector.

Three Element Tube.—This is a widely used type of tube and may be employed as a rectifier, detector, amplifier, oscillator, etc. This tube as shown in fig. 7,252 consists of a *filament, grid and plate mounted in a high vacuum.*

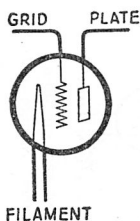


FIG. 7,259.—Three element tube consisting of filament, plate and grid.

The plate is a sheet of metal mounted so as to enclose the filament almost completely.

A free electron acts as though it were a unit of negative electricity and as such it is strongly attracted by any object having a positive or opposite charge, and will be equally strongly repelled by an object having a negative or similar charge.

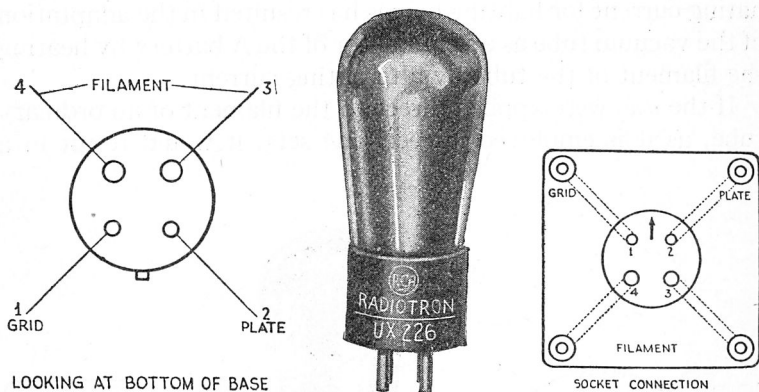
Under operating conditions, the plate of the tube *is kept positive with respect to the filament and, therefore, attracts the free electrons to it.*

Neglecting the effect of the grid for the moment, it is evident that there will be a continuous flow of electrons from the filament to the plate so long as the plate is positive with respect to the filament and so long as electrons are fed to the filament as fast as they are emitted from the filament. If this were not done, the filament would soon become positive because of the lack of negative electrons, and the plate would become

negative because of the surplus of negative charges. Under normal conditions, then, the negative terminal of a battery or dynamo is connected to the filament and the positive end is connected to the plate. The path of the electrons is then from the filament to the plate, and back through the battery or dynamo to the filament.

Since an uncontrolled flow of electricity is seldom useful, the grid is inserted in the tube *for the purpose of controlling this flow*.

If the grid be held at the same pressure as the plate, it will aid the plate in drawing electrons from the filament. If the grid be held at the same pressure as the filament, it will neither aid nor hinder the plate in drawing electrons from the filament.



FIGS. 7,260 to 7,262.—RCA Radiatron UX—226 three element amplifier tube; a.c. filament. It may be used for either radio frequency or transformer coupled audio frequency amplification. It is not ordinarily suited for use as a detector or as a power output tube.

If, however, the grid be kept negative, with respect to the filament, it will tend to drive back the electrons leaving the filament, and since the grid is between the plate and the filament, it will reduce the number of electrons which eventually reach the plate.

If the grid be only slightly negative, many electrons will reach the plate through the open spaces between the grid wires, but the grid may be held sufficiently negative so that it will repel the electrons so forcibly that none is allowed to pass it, and the number reaching the plate falls to zero.

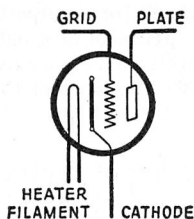
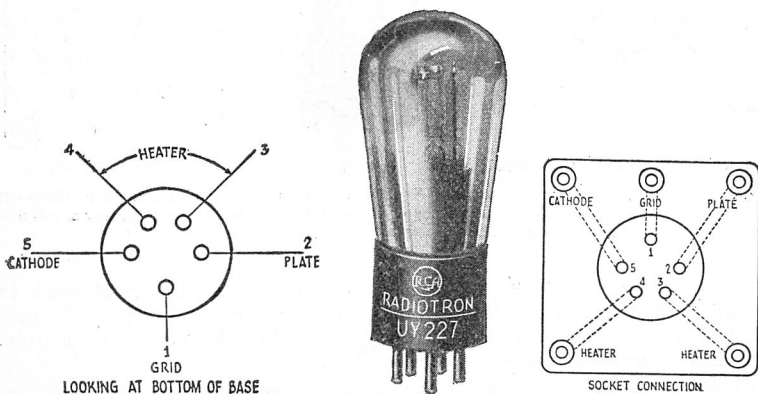


FIG. 7,263.—Four element tube consisting of heater filament, plate, grid, and cathode.

Four Element Tube.—The constantly increasing use of alternating current for lighting homes has resulted in the adaptation of the vacuum tube as an eliminator of the A battery by heating the filament of the tube by alternating current.

If the *a.c.* were applied direct to the filament of an ordinary tube, as it is employed in receiving sets, it would result in a

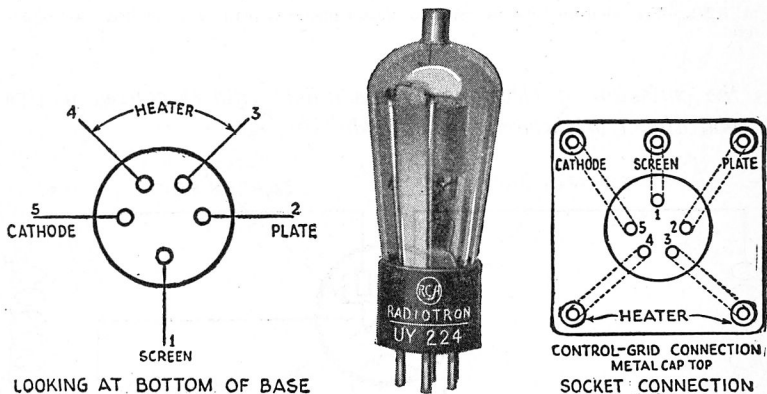


FIGS. 7,264 to 7,266.—RCA Radiotron UY-227 four element detector and amplifier tube. This is a general purpose tube containing a *heater element* which permits operation from alternating current. It is designed for use either as a detector or as an amplifier in *a.c.* radio sets operating from the light socket.

periodic variation of the voltage of the grid and plate with reference to the center of the filament.

This variation of the plate and grid voltage, would cause a corresponding variation in plate current, which would cause a disturbing noise in the head phones or loud-speaker.

To obviate noise, a fourth element is introduced in the tube, this element being a device for heating the cathode (ordinary filament) by radiation.



FIGS. 7,267 to 7,269.—RCA Radiotron UY-224 four element screen grid radio frequency amplifier. This screen grid amplifier tube contains a heater element which permits operation from alternating current. It is recommended for use primarily as a radio frequency amplifier in carefully shielded circuits especially designed for it. It may also be effectively used as a space grid tube or as a double grid tube in special circuits.

Alternating current tubes are also manufactured without the indirect heater. Such tubes have a relatively large filament and are used in circuits in which a center tapped resistor is connected across the external filament circuit.

The plate and grid circuits are then returned to the center tap of this resistor. These tubes are used extensively in output stages and to a lesser extent in radio and intermediate audio frequency amplifiers.

Five Element Tube.—The effectiveness of the four element screen grid tube, particularly as a power amplifier, is limited by secondary emission. This phenomenon is to be observed in practically all forms of electronic devices; secondary emission

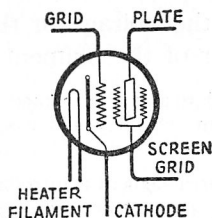


FIG. 7,270.—Five element tube consisting of heater filament, plate, grid, cathode and screen grid.

is the emission of electrons by the anode (plate) caused by the bombardment of the original cathode ray.

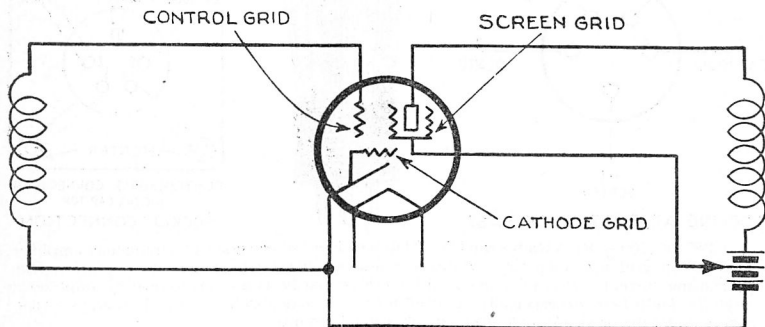


FIG. 7,271—Five element tube hook up showing how fifth element is used to eliminate secondary emission. If the fifth element be placed between the plate and the screen grid, and connected to the filament or some very low positive pressure as shown in the diagram, it is at a much lower voltage than the plate. This tends to drive the secondary emission electrons back to the plate where they belong, and prevent distortion by avoiding any subtraction from the total plate current. Thus the five element tube has the advantage of high screen grid amplification, with a large power handling capacity in addition, which makes it especially suited for power audio amplification.

As the electrons strike the plate at extremely high velocities, they knock off additional electrons. Also, the bombardment of the plate often heats it to an electron emitting temperature. In the ordinary triode, these electrons may float around for a fraction of a second and either return to the plate or join other electrons in the space charge. However, in the screen grid tube, because of the presence of another highly positive charge

on the screen grid, many electrons leave the vicinity of the plate and travel to the screen grid. These, by taking a direction exactly opposed to that of the electrons leaving the filament, partially nullify the effect of the original electrons which form the plate current.

The reason for the five element tube is *to reduce the secondary emission*, making it possible to take full advantage of the screen grid amplification in power circuits.

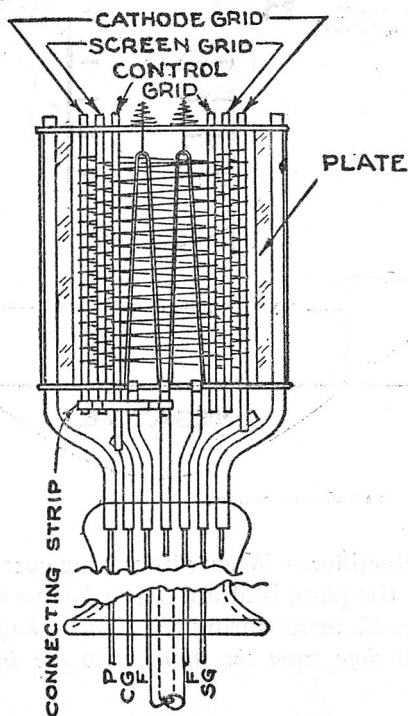
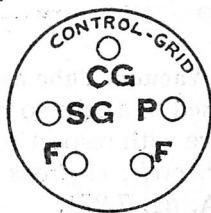


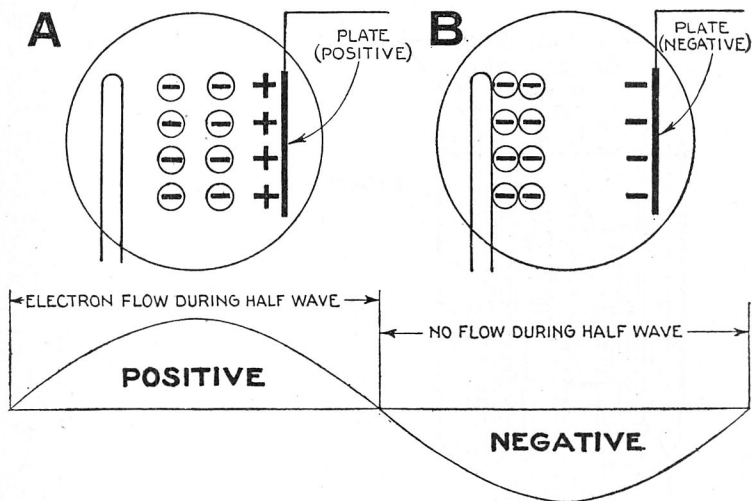
FIG. 7,272.—Interior of five element (pentode) tube showing the arrangement of the five elements. The cathode grid is connected internally to the mid-point of the filament.

FIG. 7,273.—Five element tube base showing arrangement of the prongs.



In construction, the filament, control grid and plate are the same as in the three element tube, the screen grid is used to screen the control grid from the plate and the cathode grid or fifth element is used to screen the screen grid from the plate.

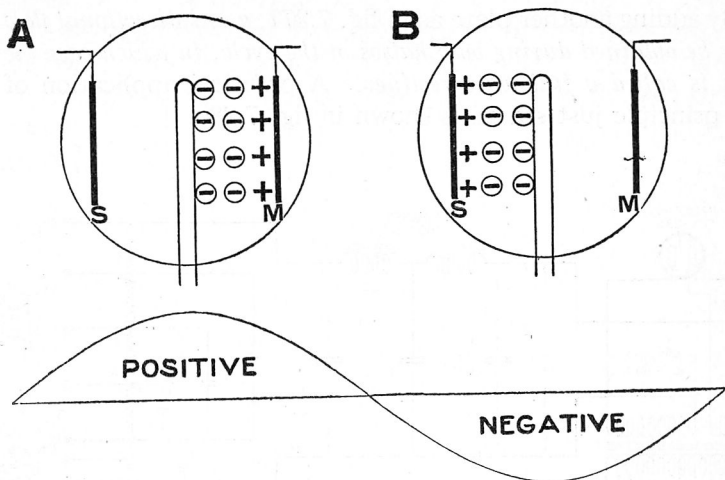
The internal construction of the five element tube is shown in fig. 7,272 and its prong arrangement in fig. 7,273.



FIGS. 7,274 to 7,276.—The vacuum tube as a *half wave rectifier*.

The Vacuum Tube as a Rectifier.—When alternating current is applied to a tube so that the plate is alternately positive and negative with respect to the filament during the *positive half* of the *a.c. cycle*, *electrons will flow from the filament to the plate as at A, fig. 7,274.*

However, when the current reverses during the negative half, no current will flow as indicated at B. A rectifier tube operating on this principle is called a *half-wave rectifier*.



FIGS. 7,277 to 7,279.—The vacuum tube as a *full wave* rectifier. In the actual apparatus the *hook up is such* that the plate M, is positive during the positive half of the cycle and the plate S, is positive during the negative half of the cycle.

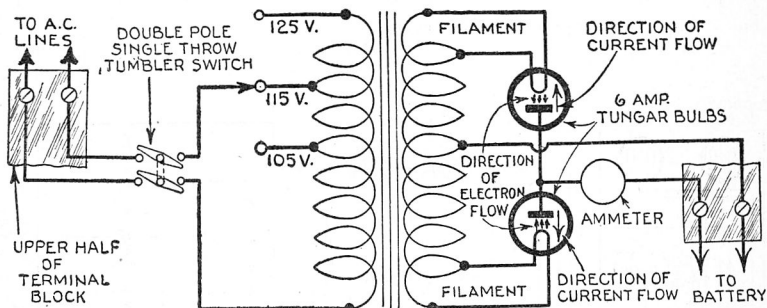


FIG. 7,280.—Wiring diagram of General Electric Tungar rectifier for charging a battery. **In operation** the ends of the secondary of the transformer are alternately + and - with respect to the center tap. Therefore, during each half cycle of alternating voltage, the plate of one or the other of the Tungar bulbs is + with respect to the filament, and a current will flow during each half cycle first through one tube and then through the other. The current always flows out of the center tap of the transformer secondary into the positive side of the storage battery, through the battery, through the ammeter, and then through one or the other of the Tungar bulbs. This current is not the steady direct current which can be obtained from a battery, but a pulsating current which flows always in the same direction. It is satisfactory for charging storage batteries but is not suitable for use where a steady direct current is required.

By adding another plate as in fig. 7,277, a *uni-directional flow* may be obtained during both halves of the cycle, in which case the tube is called a *full wave rectifier*. A practical application of the principle just stated is shown in fig. 7,280.

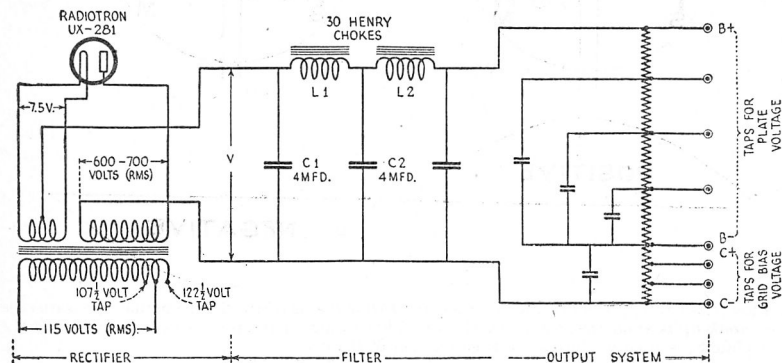


FIG. 7,281.—Typical half wave rectifier circuit.

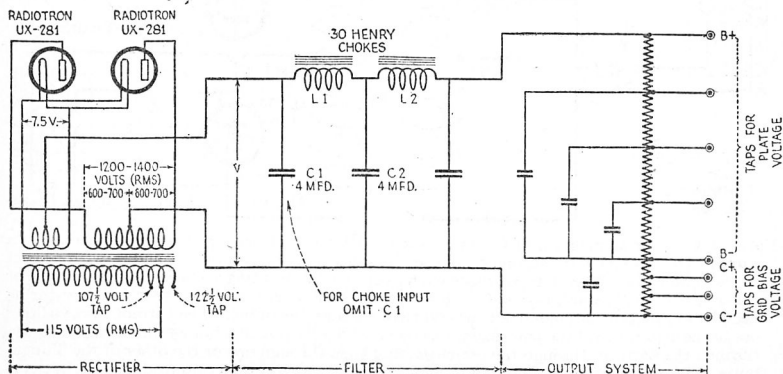


FIG. 7,282.—Typical full wave rectifier circuit.

The Vacuum Tube as a Detector.—The three element tube can be made to act as a detector by three different methods:

1. By keeping the average grid voltage negative with respect to the filament by means of the C battery. Connect positive terminal to negative leg of the filament and negative terminal to the grid circuit.

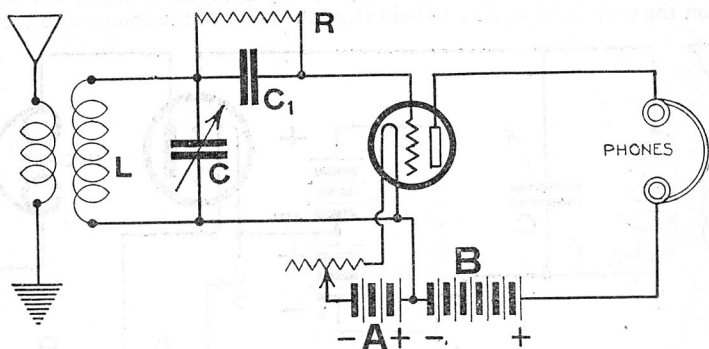


FIG. 7,283.—Circuit of grid leak and condenser detector.

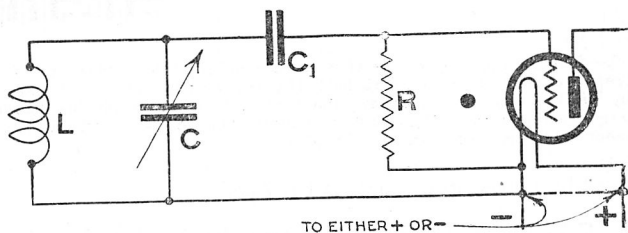


FIG. 7,284.—Circuit showing how leak may be connected from grid to filament, instead of across the grid condenser, as in fig. 7,283.

2. By keeping grid positive by aid of battery.
3. By using grid condenser and grid leak.

Figs. 7,283 and 7,284 show two hook ups for the third method.

The first method is known as plate rectification, power detection, grid bias. In this method from 4 to 6 volts are applied to the grid of the tube to influence its operation by making it more or less negative.

The grid bias is usually negative and determines the point of the characteristic curve at which the tube will operate. In a sensitive receiver, and particularly where a tube is used as an *amplifier*, it is essential to obtain as great a change of grid current as possible. The greater the change of grid current the greater the change in plate current and hence the more powerful will be the output. By applying a negative voltage on the grid, it is possible to hold it at the point of maximum response.

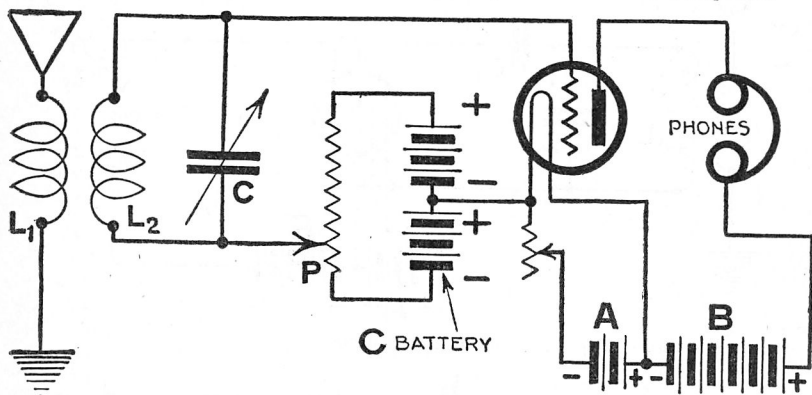


FIG. 7,285.—Detector circuit with three element tube and potentiometer control of grid bias. **In operation** the filament of the tube is heated by the A battery and the plate circuit is energized by the B battery, which maintains the plate positive. By connecting the grid return lead to the potentiometer sliding contact any desired voltage within limit of the C battery may be applied to the grid; this is called *biasing*.

A grid bias hook up is shown in fig. 7,285.

Figs. 7,283 and 7,284 show two hook ups for the third method for making a three element tube act as a detector.

This method is based upon the fact that the grid can act more or less in the same manner as the plate and attract electrons itself as soon as it becomes positive with respect to the filament.

In operation, electrons are trapped on the grid, building up a negative pressure and the high frequency voltage variations on the grid vary around

a mean grid voltage which becomes increasingly negative. This reduces the plate current, and if the grid were insulated from the rest of the circuit, the action if continued long enough, would finally reduce the plate current to a low value and the tube would be choked or stopped. To prevent this, after a wave train has been received, it is necessary to remove the accumulated negative charge from the grid in order to restore it to the initial condition for the arrival of the next wave train.

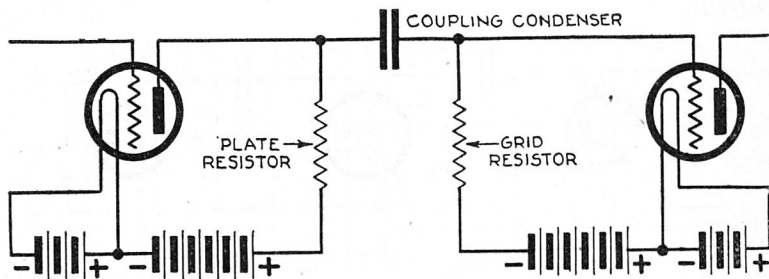


FIG. 7,286—Resistance coupled amplifier circuit

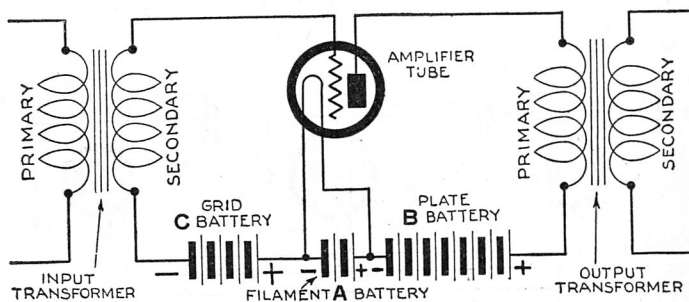


FIG. 7,287—Transformer coupled amplifier circuit.

This can be done by connecting a high resistance R , from 1 to 10 megohms, known as a *grid leak*, either across the grid condenser C , as shown in fig. 7,283, or directly between the grid and the filament as shown in fig. 7,284.

The Vacuum Tube as an Amplifier.—When a three electrode tube is used as an amplifier, *the grid is kept at a negative voltage*

with respect to the filament. This negative grid voltage is called the *grid bias* of the tube. If an alternating voltage be added to the steady negative voltage of the grid, the relative negative voltage between the grid and the filament will vary in accordance with the alternating voltage.

Variations of the grid voltage *will cause variations in the plate current*.

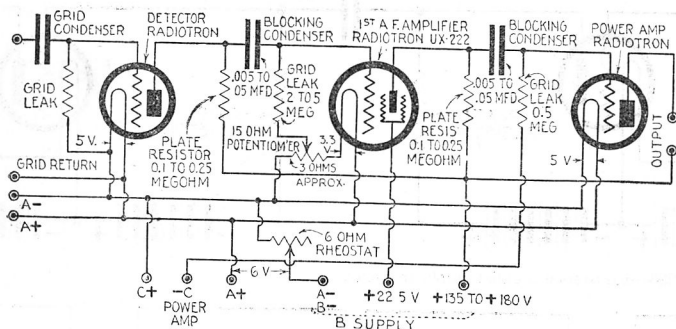


FIG. 7,288.—Typical screen grid audio amplifier circuit.

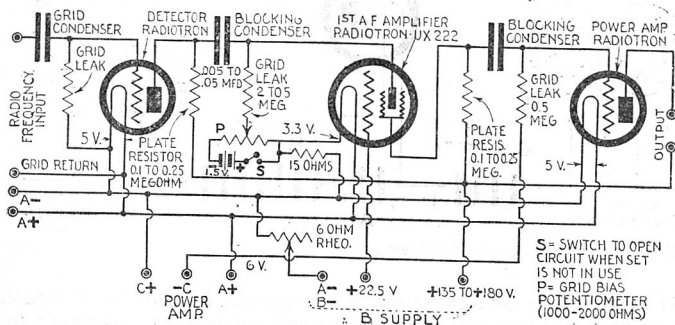


FIG. 7,289.—Typical space charge grid audio amplifier circuit.

As the grid becomes more negative the plate current decreases and as the grid voltage becomes less negative the plate current increases. If an electrical impedance, such as resistance, be placed in the plate circuit,

between the plate and the battery, a voltage will be produced across it in proportion to the plate current.

When an alternating current is impressed on the grid, *a pulsating voltage will be produced across the resistor in the plate circuit.*

If the resistance in the plate circuit be sufficiently high, the pulsations of the voltage produced in the circuit will be greater than the alternating voltage impressed on the grid. Therefore, three electrode vacuum tubes can be used to amplify (increase) variations of voltage.

Various types of tubes are used for various purposes.

Tubes designed primarily to amplify alternating voltages, where the energy output is not important, are called voltage amplifier tubes.

Tubes designed primarily to give a large energy output are called power amplifier tubes.

TEST QUESTIONS

1. What is the difference between a vacuum tube and a valve?
2. Give a classification of vacuum tubes.
3. What is an electron?
4. What is the polarity of an electron?
5. Explain electron and current flow.
6. What happens if the plate be a, positive, or b, negative, with respect to the filament?
7. Is the popular idea that electricity flows from positive to negative, correct?
8. Describe a two element tube and explain its uses.
9. How does a three element tube work?

10. *Name the various uses made of three element tubes.*
11. *What duty is performed by the grid?*
12. *Describe the four element tube.*
13. *How does the fourth element operate to eliminate noise?*
14. *What is the objection to the four element screen grid tube when used as a power amplifier?*
15. *What is secondary emission?*
16. *What is the reason for the five element tube?*
17. *Explain the operation of the vacuum tube as a rectifier.*
18. *What is the difference between a half wave rectifier and a full wave rectifier?*
19. *Draw a circuit diagram of the Tungar rectifier..*
20. *Name three methods by which the three element tube can be made to act as a detector.*
21. *Explain plate rectification.*
22. *Draw a diagram showing a grid bias hook-up.*
23. *Explain in detail how a vacuum tube is used as an amplifier.*

CHAPTER 176

Principles of Receiver Circuits

Any electrical circuit used in connection with the reception of radio is a *receiving circuit*.

The more important receiving circuits using vacuum tubes are the

- | | |
|--------------------|--|
| 1. Regenerative | 6. Neutrodyne |
| 2. Super feed back | 7. Heterodyne |
| 3. Tuned frequency | 8. Autodyne |
| 4. Reflex | 9. Super-heterodyne |
| 5. Inverse duplex | 10. Super-heterodyne with second harmonic oscillator |

There are various modifications of these circuits. The basic principles governing the working of standard receiving sets has been very clearly presented by Howard M. Jenkins, and will be included in the matter following.

Feed Back Regeneration.—The amplifying properties of the three element tube can be employed to obtain what is known as *regeneration*.

Since it is possible to have greater output energy than input energy, *part of the output may be returned to the input side*, thus resulting in amplification of energy or in regeneration.

The first advance over the simple sets was the discovery that a small part of the amplified energy might be "fed back" to the grid circuit, and

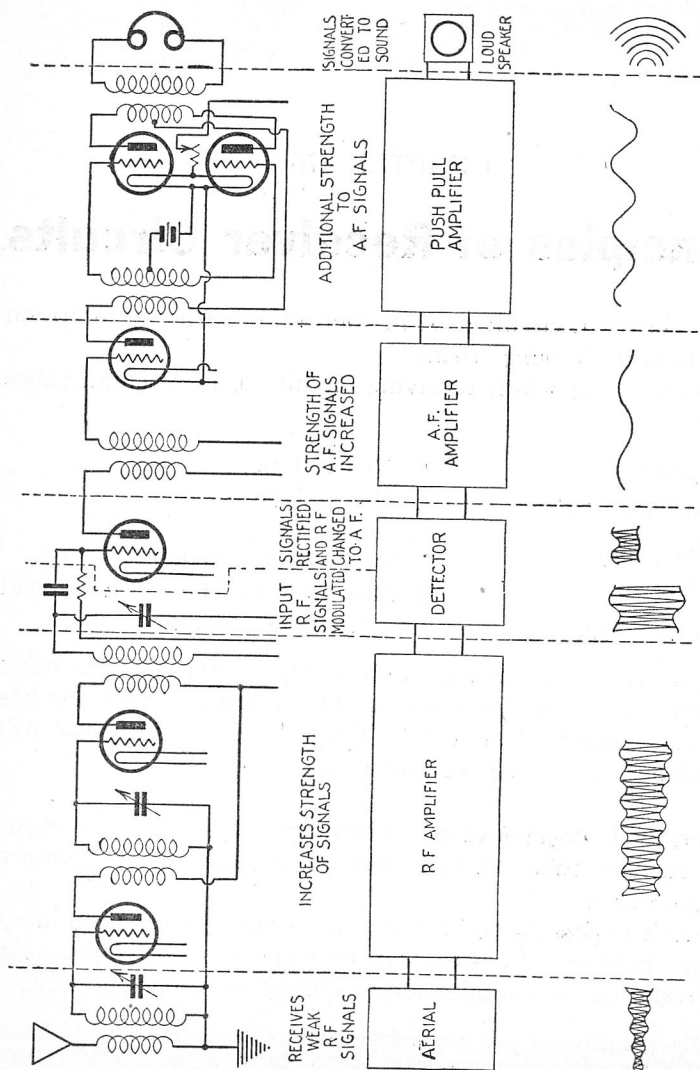
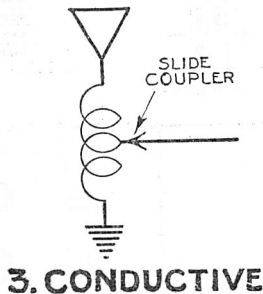
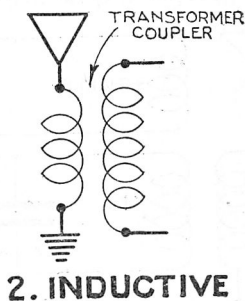
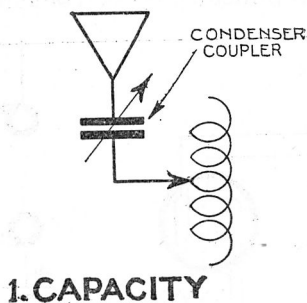


FIG. 7.290.—Combination diagram showing arrangement of the different units of a typical receiver with circuit diagram and wave chart showing how the radio waves are modified by each unit; that is, how the inaudible waves first picked up by the aerial undergo successive changes en route to the loud speaker.

combining with the incoming signal further increase the plate output. This process, if led to continue, and if the power feed back be enough to counteract all losses in the circuit, will build itself up until the circuit "oscillates" with disastrous results to the clarity of the signal. The best amount of feed back is just below this point of oscillation.



FIGS. 7,291 to 7,293.—Circuit diagrams showing various methods of coupling. Fig. 7,291, electrostatic; fig. 7,292, inductive; fig. 7,293, conductive.

There are three methods of feeding back the plate current to the grid.

1. Capacity coupling;
2. Conductive coupling;
3. Inductive coupling.

All of these return part of the amplified energy to the grid circuit.

Super Feed Back.—With the ordinary sets there is a limit to the possible regeneration. This difficulty is overcome in the

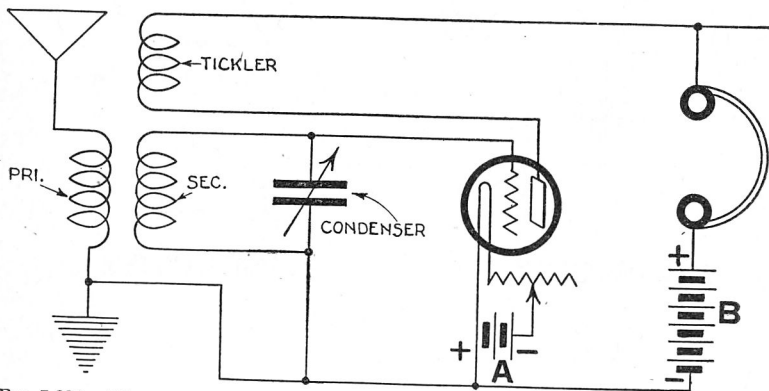


FIG. 7,294.—Diagram illustrating principle of feed back regeneration.

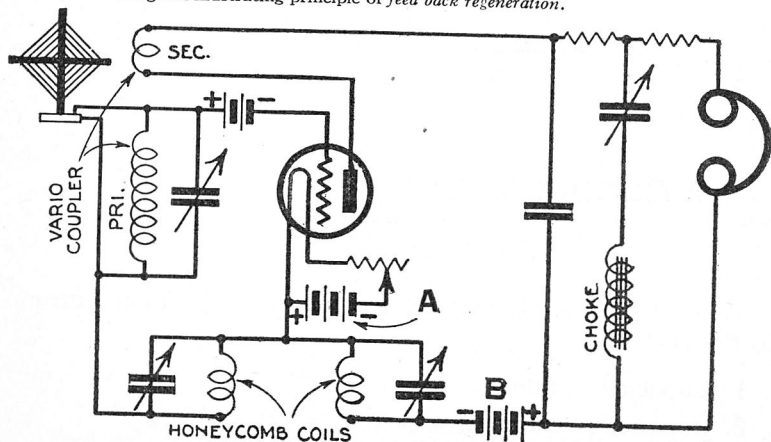


FIG. 7,295.—Diagram illustrating principle of super feed back.

super-regenerative sets. These make use of the principle that by introducing into the circuit an alternator, whose frequency is above audibility, the feed back will periodically be raised and lowered about the oscillation point. By this means a tremendous feed back is possible, although the set is somewhat "critical" and difficult to adjust. The alternating current is usually produced by an electron tube oscillator, which may be a separate tube, or the detector tube itself.

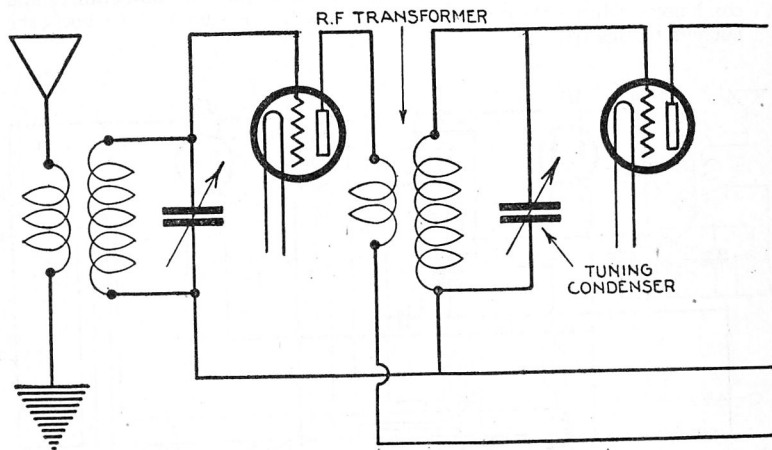


FIG. 7,296.—Diagram illustrating the principle of tuned radio frequency. The usual method of tuning is by means of a variable condenser in parallel with the secondary of the radio frequency transformer. A potentiometer is used to control oscillations, as the greatest amplification is obtained when the circuits are operated just at the point before self-oscillation starts.

Tuned Radio Frequency.—The word tuned is defined as *brought into resonance with the desired signal*. A tuned radio frequency circuit is one in which the radio frequency amplifier circuits may be tuned to the desired wave lengths by varying the inductance or the capacity or both although the usual method of tuning is by means of a variable condenser in parallel with the secondary of the radio frequency transformer.

The Reflex Principle.—The reflex idea is one of many which aim to *extract the maximum use of a tube or a group of tubes.*

Briefly, the incoming wave is passed through radio frequency amplification, is then rectified by the detector, and then passed again through the same tubes as used for the radio frequency amplification, but which now functions as audio frequency amplifiers.

The current is guided through this tortuous path by inductances and condensers which, if proper values be used, are supposed to keep the current to this path.

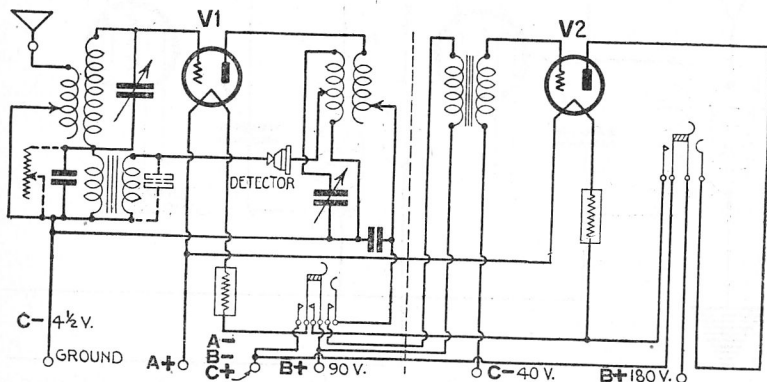


FIG. 7,297.—Wiring diagram of the Carborundum single tube reflex receiver modified with a second audio stage amplifier to provide good loud speaker volume on strong signals. V2 is the added tube arranged as a second stage of a.f. amplification.

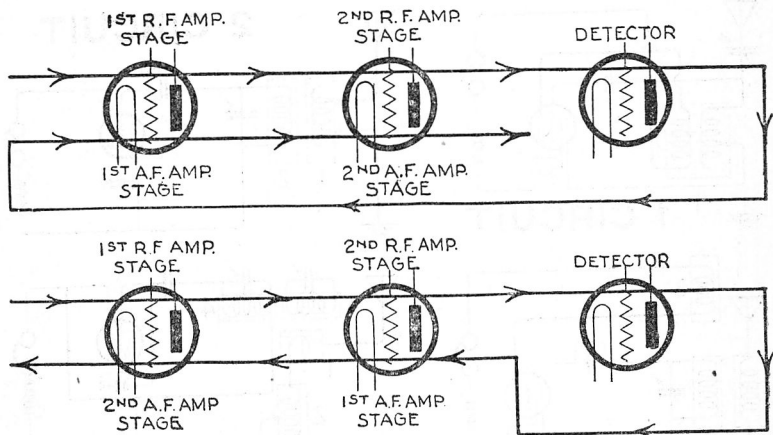
The reflex circuit was invented by Marius Latour.

A typical four tube reflex set uses the second and third tubes as amplifiers simultaneously for both the radio and the audio frequency amplification.

As a result the four tubes are made to produce the effect of six. Reflexing may be accomplished in a number of different ways. In some cases all

the tubes are made to work twice. In other cases, only a part of the tubes are used for dual amplification.

Inverse Duplex Principle.—A slight commercial variation of the reflex circuit produces the so called *inverse duplex*. This is essentially a reflex set, the refinement being that *the work is evenly distributed between the tubes* so that none is overloaded as in the straight reflex.



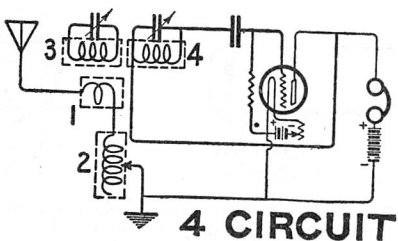
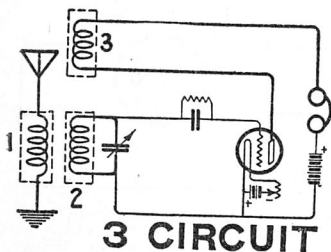
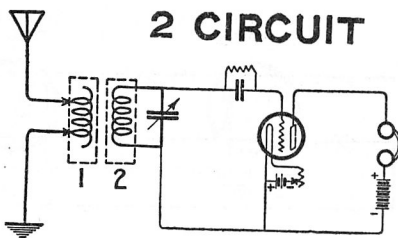
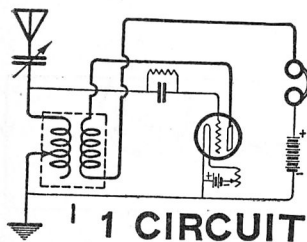
FIGS. 7,298 and 7,299.—Diagrams showing current paths in ordinary reflex circuit and in inverse duplex circuit. In the inverse duplex circuit, fig. 7,299, the incoming signal reaches the first tube where it is amplified at radio frequencies and passes to the second tube, where it is again amplified at radio frequencies. From the second radio frequency tube, it is passed to the detector tube, where it is converted to audio frequency. The current then flows back to the second radio frequency tube which is now used as an audio frequency amplifier. Thence it flows to the first radio frequency tube which acts as the second stage of audio frequency amplification.

That is, the tubes which are reflexed operate more efficiently since the relatively weak radio currents pass through the same tube as the stronger audio currents and vice-versa.

The inverse duplex circuit (invented by David Grimes), like the reflex circuit uses the tubes for double duty, the first radio frequency tube being employed also as a second audio frequency tube and the second radio frequency tube also as a first audio frequency tube.

Neutrodyne Principle.—The neutrodyne circuit is the invention of L. A. Hazeltine. The typical neutrodyne receiving set uses five tubes, employing *two stages of tuned and neutralized radio frequency amplification, with detector and two audio frequency stages*.

In the neutrodyne circuit the feed back tendency of the radio frequency amplification with consequent oscillation, is eliminated. This is done by



FIGS. 7,300 to 7,303.—Diagram illustrating the designations, one circuit, two circuit, three circuit and four circuit sets.

specially designed small size neutralizing condensers placed between successive tubes. The special neutralizing condensers are called *neutrodons*. The capacity of these is very low, being approximately equal to the internal capacity of a vacuum tube. By reason of this equality, any tendency of a large amount of radio frequency current to pass back through the tube through the grid is defeated and instead is neutralized by the combination of the neutralizing capacities, the inter-element capacity of the vacuum tubes and the secondary windings of the tuned radio frequency transformers. This effect is in reality a bucking one, since the current is made to take two paths.

Each neutralizing condenser must be adjusted so that its capacity will equal that of the vacuum tube it is connected with.

This makes possible higher ratios of radio frequency amplifications and if the transformers be of the tuned circuit type (by means of a variable condenser shunted across the secondary) the set is made very selective.

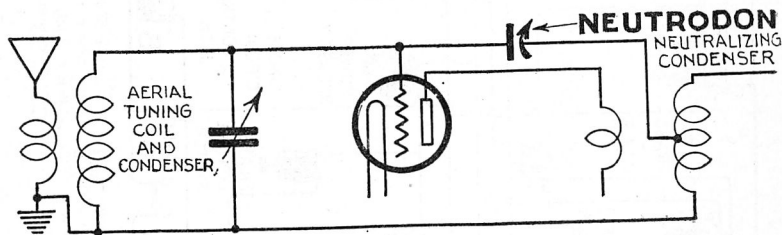


FIG. 7,304.—Diagram illustrating the *neutrodyne* principle.



FIG. 7,305.—Neutrodon variable condenser for neutralizing radio frequency circuits in neutrodyne receivers.

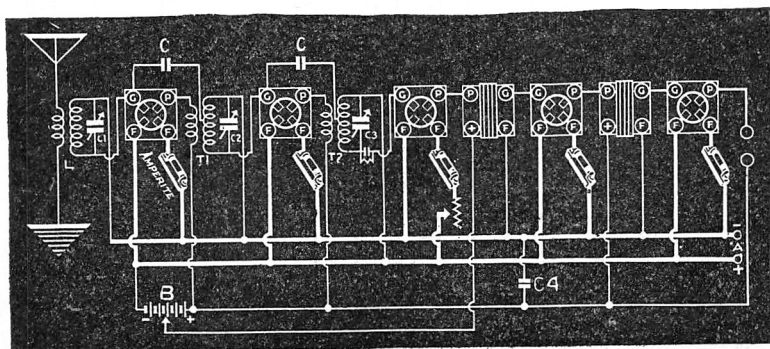


FIG. 7,306.—Five tube neutrodyne set. If properly built and adjusted the neutrodyne circuit combines ease of control with selectivity. It is excellent for both local and distant reception.

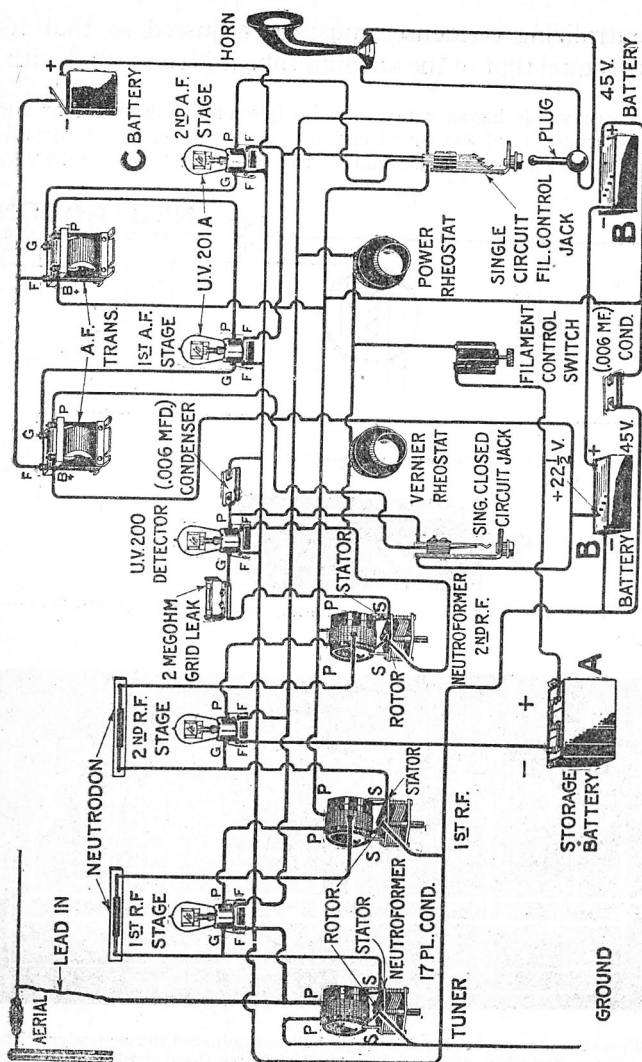


FIG. 7,307.—*Neutrodyne*.—This set embodies the principle of *tuned radio frequency*. The advantage of this over the untuned type lies in the fact that in the latter a frequency peak is reached too quickly. This limits the receiver to the wave band over which the radio frequency transformers will function. In the neutrodyne, however, the peak is so high that the receiver will function equally well on long and short wave lengths. It is also famous for its long distance reception. Either an outside aerial or a loop may be used.

The neutrodyne principle is applied to the radio frequency alone, the subsequent amplification circuit after the detector, if any, may be straight non-regenerative amplification, or the same circuit may be made regenerative by adding a variometer; or perhaps the set may be re-flexed.

The Heterodyne and Autodyne Principles.—This is the principle of the formation of a “beat” note by the superimposition on the incoming wave of a second wave of a slightly different frequency, either a little higher or lower than the incoming or fundamental wave.

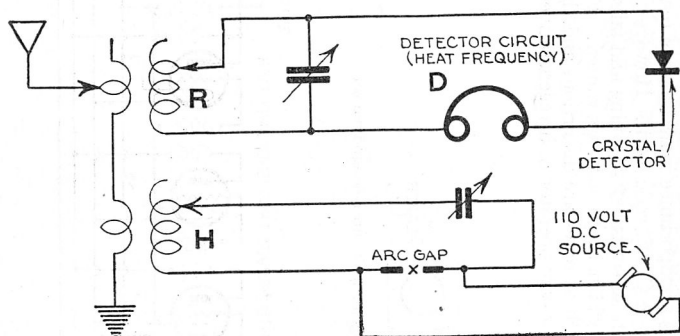


FIG. 7,308—Diagram illustrating the heterodyne principle. If R, be tuned to incoming signal wave length, and H, to a different frequency the difference is the beat frequency which will be rectified by the detector and audible in the head phones D.

This beat note will pass through the detector and be made audible in the phones in the ordinary manner. There are two advantages of this arrangement; first, the incoming wave is materially strengthened by the added wave; second, the selectivity is greatly increased, for not only is the regular resonant circuit employed but the formation of the beat note itself is a highly selective process.

The added alternating current wave may be produced by a separate electron tube oscillator, in which case the set is heterodyne, or the detector tube may be made to function as an oscillator, also in which case the set is *autodyne*.

The beat note effect may, in fact, be present in almost any set which employs tubes, notably the regenerative circuits. Rightly understood and utilized it is of importance in all kinds of reception and is necessary for the best results in C. W. code work. However, the average amateur does not realize when his set is heterodyning and fails to diagnose and allow for the condition, which is, to him, unwanted. Familiar manifestations of the pressure of beat notes are distortion, and the whistles, squeals and howls with which every operator of a regenerative set is acquainted.

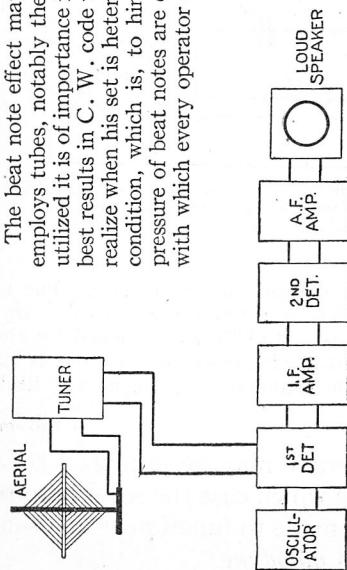


FIG. 7,309.—Block diagram showing general arrangement of super-heterodyne set.

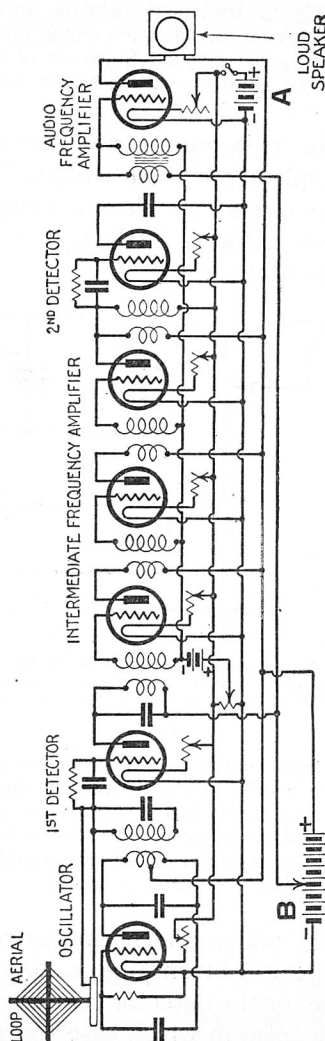


FIG. 7,310—Diagram illustrating the essentials of super-heterodyne set. This typical six tube set comprises an oscillator, first detector, two intermediate stages, second detector, and one audio frequency stage.

The Super-Heterodyne Principle.—The super-heterodyne circuit combines the advantages of the audio frequency and the radio frequency amplification. From a structural and

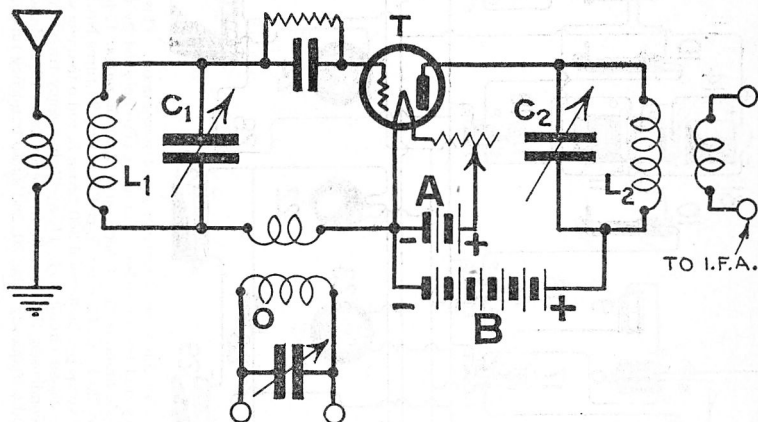
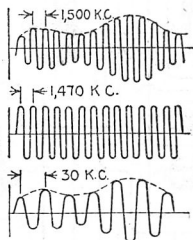


FIG. 7,311.—Frequency changing portion of super-heterodyne circuit. A vacuum tube T, is connected as a detector and has a tuned grid circuit L_1 , C_1 , and a tuned plate circuit L_2 , C_2 . Circuit O, which has a steady high frequency current flowing in it, is coupled to the grid circuit by the coils. *In operation*, a resultant or beat wave is obtained as in figs. 7,312 to 7,314.



Figs. 7,312 to 7,314.—Heterodyning of two currents. Assume that the circuit L_1 , C_1 (in fig. 7,311), is tuned to an incoming signal at 1,500 kilocycles and that circuit O, is connected to an oscillator adjusted to have a frequency of 1,470 kilocycles. This gives a combination of two frequencies impressed across the grid circuit of the tube. These two frequencies combine to produce a resulting wave, as shown in 7,314, which has a frequency equal to the difference of the two waves, or 30 kilocycles. This different frequency which will be present in the plate circuit is called the intermediate frequency, and is always a lower frequency than either of the other two.

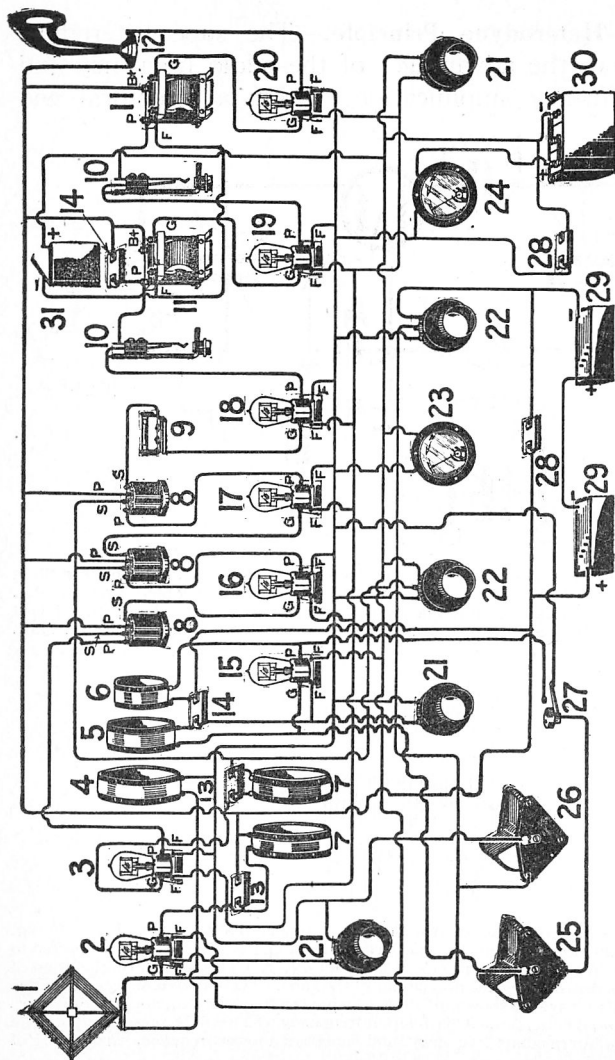


Fig. 7,315.—*Super-heterodyne*.—Trans-continental reception with this type of receiver is not uncommon. This set employs an oscillator and two detectors, three stages of radio frequency and two of audio. Tuning is accomplished by means of two variable condensers and one or two potentiometers. An outside antenna is not necessary. **List of parts:** 1, loop aerial; 2, first detector tube; 3, oscillator tube; 4, coil $4''$ dia. 6 turns No. 20 D. C. wire; 5, coil $3\frac{3}{4}''$ dia. 20 turns No. 20, D. C. C. wire; 6, coil $2\frac{3}{4}''$ dia. 2 layers, 20 turns each; 7, 25 layers, 12 turns per layer total 300 turns; 8, radio frequency transformer; 9, 2 megohm grid leak and .00025 fixed condenser; 10, single closed circuit jack; 11, audio frequency transformer; 12, loud speaker; 13, .00025 fixed mica condensers; 14, .001 fixed mica condenser; 15, 1st radio frequency tube; 16, 2nd radio frequency tube; 17, 3rd radio frequency tube; 18, 2nd detector; 19, 1st audio frequency tube; 20, 2nd audio frequency tube; 21, rheostats;

flexibility point of view, audio frequency is the ideal, while from an electrical standpoint, radio frequency is superior. Super-heterodyne combines both of these advantages, by converting the incoming high frequency wave to a beat wave of intermediate frequency by means of superimposed oscillations.

Briefly, the super-heterodyne method of reception is one in which current is generated by a local oscillator at a frequency which, after combining with the original signal current, will be converted into an intermediate frequency beat current.

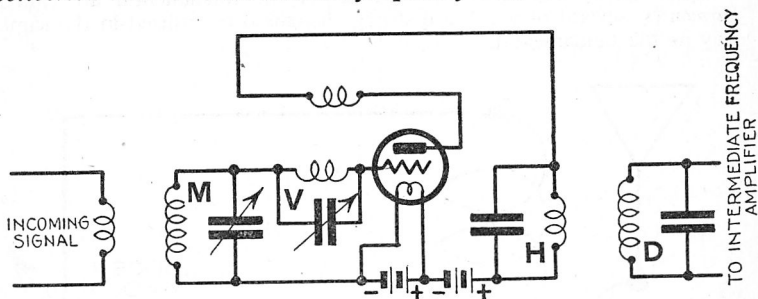


FIG. 7,316.—Diagram illustrating principle of *super-heterodyne* with second harmonic oscillator. The oscillatory circuit M, is tuned to the frequency of the incoming signal, the circuit V, is tuned to one-half the frequency of the incoming signal plus or minus one-half the intermediate frequency, and the circuits H, and D, are tuned to the intermediate frequency.

The intermediate beat current, which is low in frequency, can be amplified with minimum loss due to inter-electrode capacity, and then passed through the detector tube to be converted again, this time into an audio frequency current which is capable of reproducing the original signal wave in the phone or loud speaker.

This frequency as stated is sufficiently low to permit the use of audio frequency type amplifying transformers with their attendant advantages, and yet retain the advantage of amplification before detection. After the detector, the rectified wave may be still further amplified in the regular

FIG. 7,315.—Text continued.

22, 400 ohm potentiometers; 23, volt meter; 24, ammeter; 25, .001 vernier variable condenser (43 plates); 26, .0005 vernier variable condenser (23 plates); 27, switch; 28, .002 by pass condenser; 29, 45 volts B bat.; 30, 6 volts storage A bat.; 31, C bat.

manner. This arrangement is theoretically one of the best methods for the reception of short wave lengths.

Super-Heterodyne with Second Harmonic Oscillator.—In this hook up the second harmonic oscillator is operated on the principle that *an oscillating vacuum tube circuit generates a current of fundamental frequency, and also produces other oscillations which are multiples of the fundamental frequency.*

These upper frequencies in multiples of the fundamental are called *harmonics*, several of which are strong enough to be utilized in the same way as the fundamental.

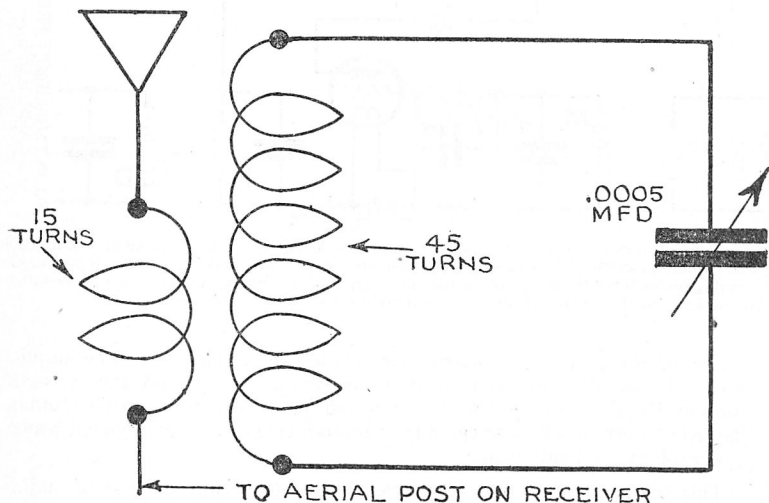


FIG. 7,317.—Super wave trap. This is a tuned oscillatory circuit and is used to eliminate interference. *It consists of* an inductance coil having a primary and a secondary winding. The variable condenser is placed in the secondary winding circuit as shown.

Another feature of the circuit is the reduction in the number of tubes accomplished by reflex action. The radio frequency tube is made to perform the double duty of amplifying both the intermediate current and the incoming signal current.

Wave Trap.—A successful method of cutting out local interference is by means of a wave trap. The trap comprises a variable condenser placed in parallel with a coil. A switch across the coil permits switching out the trap and again receiving broadcasting from the local stations.

TEST QUESTIONS

1. *What is a receiving circuit?*
2. *Name the circuits used in radio sets.*
3. *Explain feed back regeneration.*
4. *Name three methods of feeding back the plate current to the grid.*
5. *What principle is employed to obtain super feed back?*
6. *What difficulty is encountered in super regenerative sets?*
7. *Define tuned radio frequency.*
8. *What is the usual method of tuning in a tuned radio frequency set?*
9. *Explain the reflex principle.*
10. *What use is made of the second and third tubes in a typical four tube reflex set?*
11. *State the inverse duplex principle.*
12. *How are the tubes used in the inverse duplex circuit?*
13. *How many tubes are used in a typical neutrodyne set?*
14. *How does a neutrodyne set work?*
15. *How is each neutralizing condenser adjusted?*

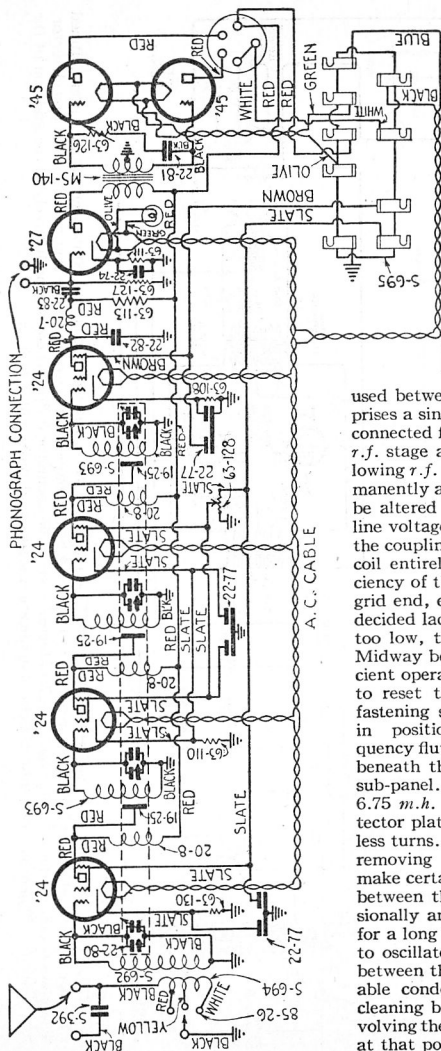
16. What name is given to a neutralizing condenser?
17. How is a high radio frequency amplification obtained in neutrodyne sets?
18. Draw a diagram of a neutrodyne set.
19. State the heterodyne and autodyne principles.
20. What is a beat note?
21. How does an autodyne set differ from a heterodyne set?
22. State, 1, the super-heterodyne principle, 2, super-heterodyne with second harmonic oscillator.
23. What is a wave trap?

CHAPTER 177

Radio Circuit Diagrams

FIG. 7,318.—Circuit diagram of super-Zenith receiver. *The circuit comprises:* three stages of screen grid $\tau.f.$, a screen grid power detector, one resistance coupled stage and one stage of push pull audio amplification. A special capacity coupling is

used between the $\tau.f.$ stages. The coupling comprises a single band of bus bar wire. This band is connected from the plate terminal of the preceding $\tau.f.$ stage and coupled to the grid coil of the following $\tau.f.$ stage. The position of this band is permanently adjusted at the factory and should never be altered or tampered with unless the available line voltage be extremely low. The distance from the coupling band to the grid or top end of the $\tau.f.$ coil entirely governs the stage coupling and efficiency of the set. If this band be too close to the grid end, excessive coupling will result, causing a decided lack of selectivity. If the band be placed too low, the result will be a lack of sensitivity. Midway between the coil winding is the most efficient operating position. If it be found necessary to reset this band, insulating cement or other fastening substance should be applied to hold it in position. Loose vibration would cause frequency flutter. The $\tau.f.$ plate chokes are concealed beneath the $\tau.f.$ coil base, between the base and sub-panel. These chokes have an inductance of 6.75 m.h. and can be distinguished from the detector plate choke by the fact that they have 150 less turns. If an occasion arise which necessitates removing an $\tau.f.$ choke, the serviceman should make certain that the $\frac{1}{8}$ in. spacing is maintained between the choke and the $\tau.f.$ coil base. Occasionally and especially if the receiver remain idle for a long length of time, it may have a tendency to oscillate. This is always due to poor contact between the wipers and rotor bearings of the variable condenser gang. It may be overcome by cleaning both parts with fine sandpaper or by revolving the dial several times to remove oxidation at that point.



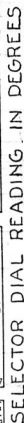
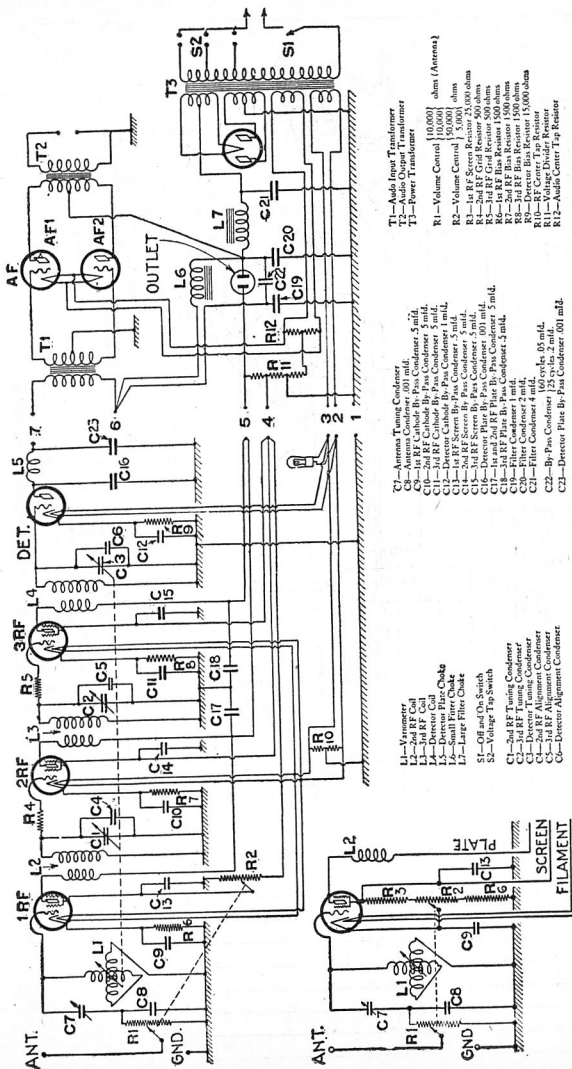


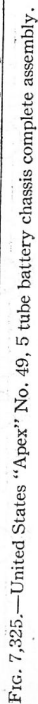
FIG. 7.320.—Diagram of Bosch model 48 receiver showing the tuning amplifying action of the various stages. The illustration is divided into six sections, lettered A to F. The graphs of these sections tend to show the type of reception which might be expected if ear phones could be connected successively in each of the receiver sections at the points marked X. The ten horizontal divisions of each graph represent the corresponding number of degrees on the tuning dial between 45 and 55. The vertical divisions represent comparative audibility.

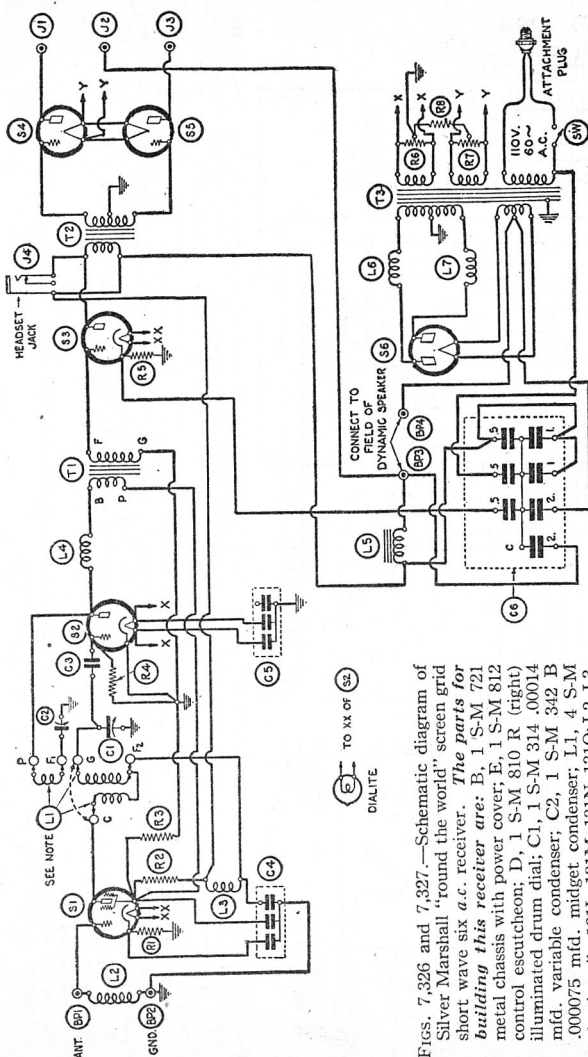


FIGS. 7,323 and 7,324.—Schematic wiring diagram Bosch model 48 receiver. In fig. 7,324 follow this portion of diagram for sets using volume control having resistances of 10,000 and 5,000 ohms.

FIG. 7,322.—Text continued.

7 1/2 x 18 x 1 1/2 ins., drilled with all mounting and wiring holes; 4 No. 37 metal sub-panel brackets; 2 No. 1611 .00016 mfd. variable condensers; 1 No. 1613 .00025 mfd. variable condenser with bakelite knob; 2 No. 1282 illuminated vernier dials; 1 No. 906 rheostat, 6 ohms; 1 No. 961 tapped resistor; 2 No. 600 special Super-Wasp shield cans; 1 No. J5 midjet condenser, 5 plates; 2 No. 391 audio amplifying transformers; 2 No. 212 five prong sockets, for plug in coils; 2 No. 213 four prong sockets, for audio tubes; 2 No. 206 four prong shock proof sockets, for 222 and detector tubes; 2 pairs grid leak clips; 1 No. 758 3 megohm grid leak; 1 No. 750 100,000 ohm grid leak; 1 No. 50B fixed condenser, .0001 mfd.; 5 No. 59 fixed condensers, .01 mfd.; 1 No. 130 RF choke coil; 2 sets of plug in coils, 4, packages of hardware.





FIGS. 7,326 and 7,327.—Schematic diagram of Silver Marshall "round the world" screen grid short wave six a.c. receiver. *The parts for building this receiver are:*

B, 1 S-M 721 metal chassis with power cover; E, 1 S-M 812 control escutcheon; D, 1 S-M 810 R (right) illuminated drum dial; C1, 1 S-M 314 .00014 mfd. variable capacitor; C2, 1 S-M 342 B .000075 mfd. midge capacitor; L1, 4 S-M plug in coils, 131L, 131M, 131N, 131O; L2, L3, L4, 3 S-M 277 short wave τ f. chokes; L6 and L7, 2 S-M 275 τ f. chokes; L5, 1 S-M 338 filter choke; also the following: SH1, 1 SH2, 2 S-M 636 tube shields; T1, 1 S-M 260S audio transformer; T2, 1 S-M 270U push pull input transformer; T3, 1 S-M 336U power transformer and 1 S-M 818 hook up wire; C3, 1 Polymet .00015 mfd. small moulded capacitor; C4 and C5, 2 Potter 30B by-pass capacitor banks; C6, 1 Potter 674C filter capacitor block; S1, 1 C-R 224 tube socket; S2, S3 and S7, 3 C-R 227 tube socket; S4 and S5, 2 C-R 245 tube socket; S6, 1 C-R 280 tube socket; R2 and R3, 2 Durham 10,000 ohm, 2 watt resistors (green); R4, 1 Durham 2 megohm, 1 watt resistor (red); R5, 1 Durham 200 ohm 1 watt resistor (white); R6 and R7, 2 Yaxley 840C 40 ohm CT resistor; J1, J2 and J3, 3 Yaxley 422 insulated tip jacks; J4, 1 Carter 2A closed circuit jack; R1, 1 Carter RU 400-400 ohm resistor; R8, 1 Ohio carbon 800 ohm 3 watt resistor (green); SW, 1 H & H 1561 rotary on and off switch; BP1, BP2, BP3 and BP4, 4 moulded binding posts; 2 KK817 brown wood knobs; 1 cord and plug, 35% $\times$ $\frac{1}{2}$ in. RH machine screws; 5 $1\frac{1}{2}$ $\times$ $\frac{5}{16}$ RH machine screws; 2 $1\frac{1}{4}$ $\times$ $\frac{1}{4}$ hollow

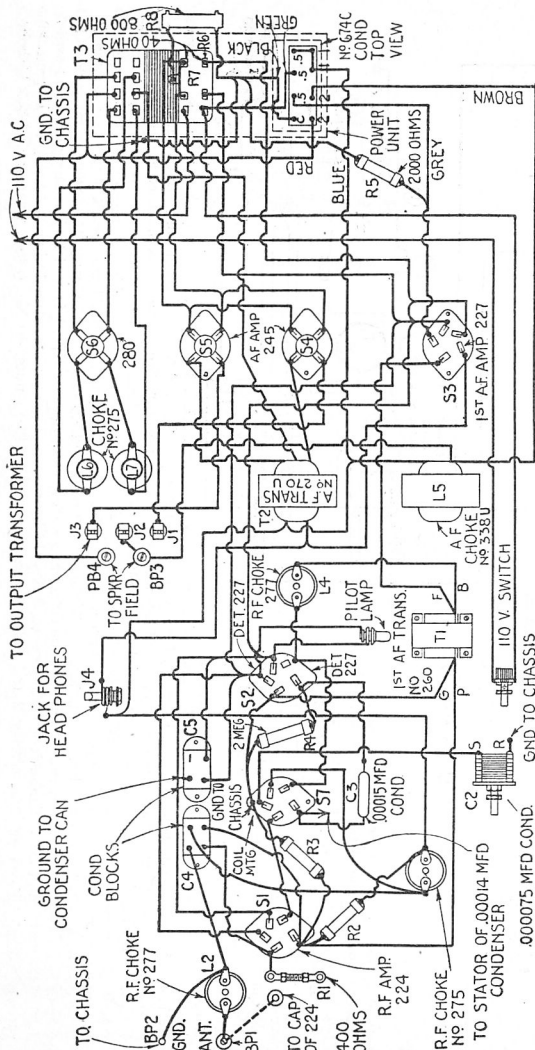


FIG. 7,328.—Bottom view of Silver-Marshall "round-the-world" screen grid short wave six *a.c.* receiver showing in detail the placing of parts and wires. **It comprises:** a fully *a.c.* operated screen grid short wave receiver with self contained power supply. There are four plug in coils. The receiver tunes from 16.6 to 195 meters and by means of two additional plug in coils, its range is increased up to 592 meters. It may be used with an indoor or outdoor antenna. The circuit consists of one stage of untuned *a.c.* screen grid *r.f.* amplification (224 tube) followed by a 227 tube tuned detector employing plug in coils with controllable regeneration. The detector is transformer coupled to a type 227 first audio stage which in turn feeds a 245 push pull power output stage. The power supply, operating from *a.c.* 105 to 120 volt, 50 to 60 cycle *a.c.* lighting circuit, provides all A, B, and C power for the receiver, and field power for an S-M type 851 *d.c.* dynamic speaker the field of which (1900 ohms) is included in the power supply filter circuit. The receiver is provided with three controls.

FIGS. 7,326 and 7,327.—*Text continued.*

coil studs; 7 soldering lugs; 3 sets (one plain, one extruded) binding post insulated washers; 3 extruded tip jack washers; 3 plain instrument washers; 4 ft. No. 14 stranded wire; 1 grid clip.

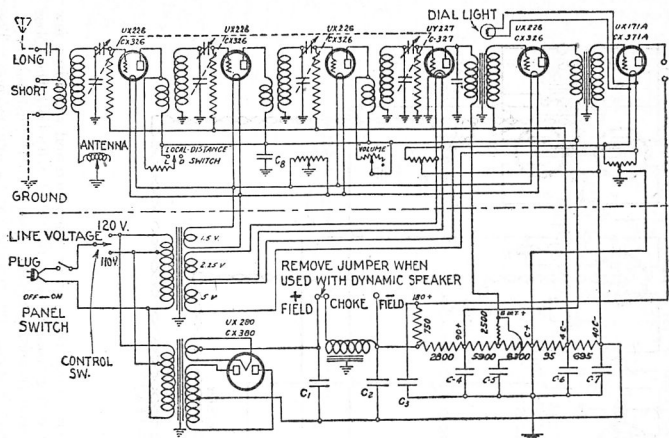


FIG. 7,329.—Wiring diagram for Grebe synchrophase *a.c.* six receiver designed to operate on 110 volt 50-60 cycle *a.c.* supply.

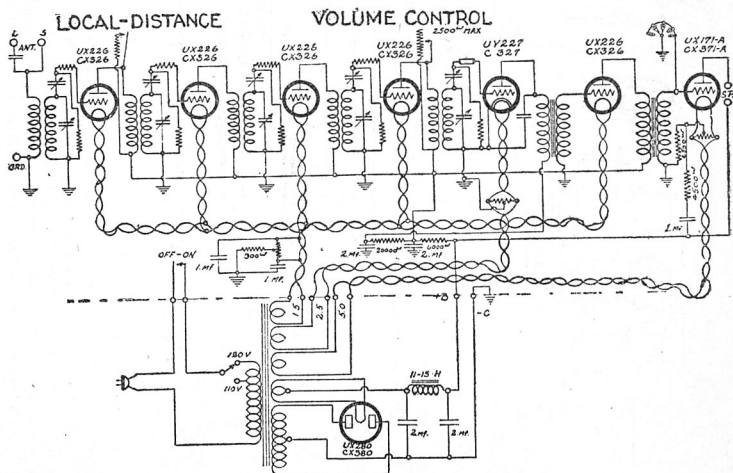
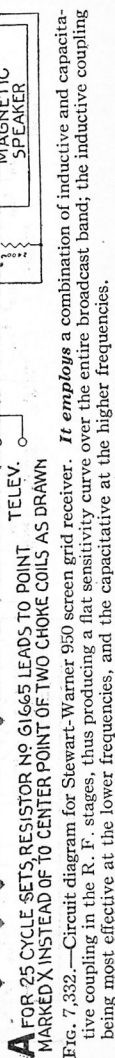


FIG. 7,330.—Wiring diagram for Grebe synchrophase *a.c.* seven receiver. It was necessary in the design of this instrument for *a.c.* operation, to include an external power unit to supply the filament, plate and grid bias voltages.



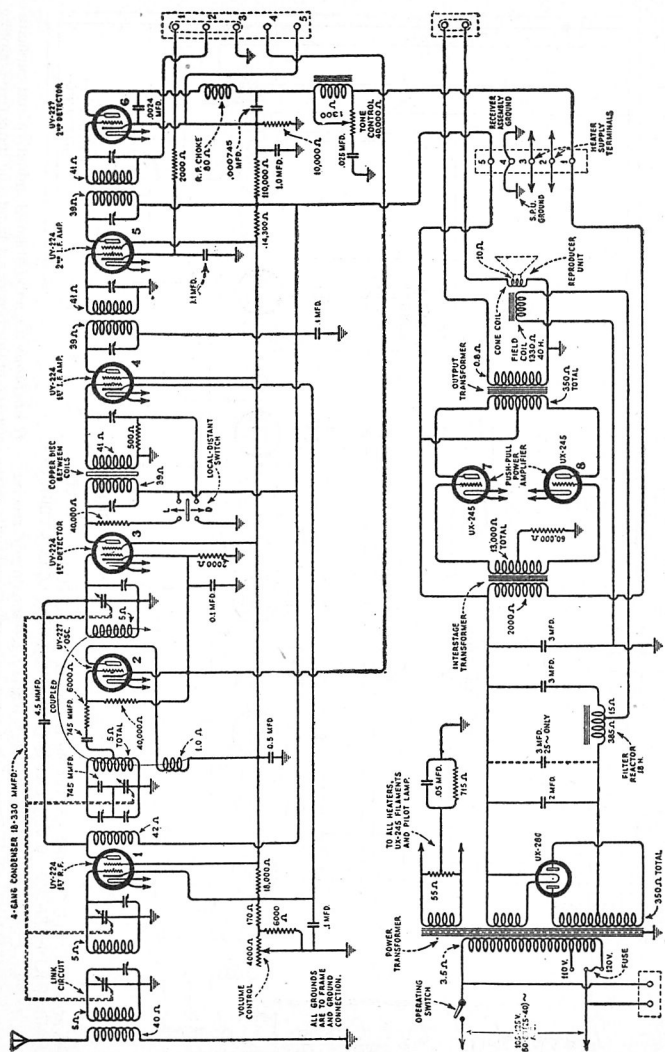


FIG. 7.333.—Circuit diagram of RCA a.c. screen grid super-heterodyne Radiola 82. Voltage 105-125; frequency 50-60 or 25-40; power consumption 120 watts, 1 stage *r.f.*; 2 intermediate stages; 1st stage (push pull) *a.f.* The *tone control* consists of a 40,000 ohm potentiometer in series with a .025 *mfd.* fixed condenser. This arrangement is shunted around a choke placed in the second detector plate circuit. With the resistor arm at the extreme "high" position, the reactor is shorted and the full amount of the resistance is placed in series with the condenser, thus giving the normal fidelity of the receiver. As the potentiometer arm is

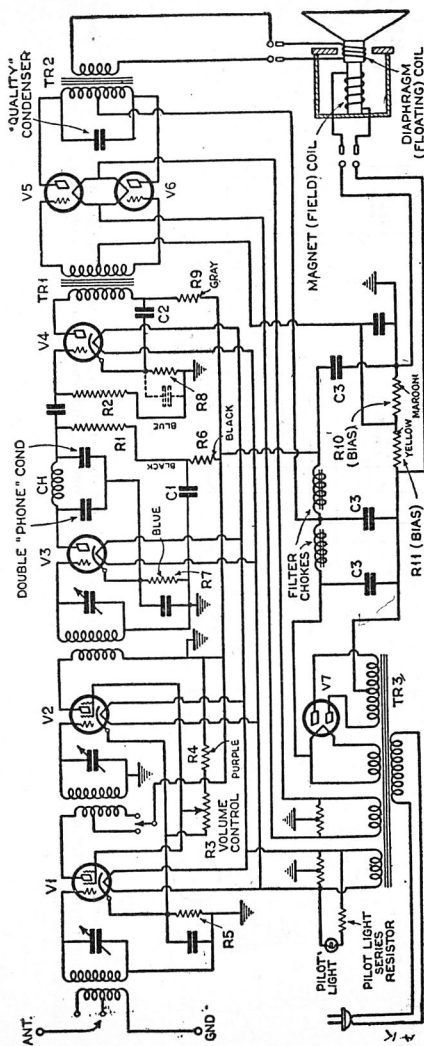


FIG. 7,334.—Atwater Kent Model 55 six tube (and rectifier) *a.c.* receiver. This model does not require a long aerial. Two aerial posts are provided on the set marked "long antenna and short antenna." The long aerial post will give greater selectivity and should be used if the aerial be 30 ft. or more in length. The short aerial post should be used if a very short (inside) aerial be employed. If extreme selectivity be desired use a short aerial connected to the long aerial post. Indoor aerials for Model 55 should be erected as far as possible away from grounded metal, such as pipes, electric wiring, etc. Ground connection *must* be used with Model 55. This set will also not operate (as some *a.c.* sets do) with either aerial post connected to the ground. The two *a.f.* output tubes used in the audio stage should be matched on a tube tester, otherwise the set may hum. Do not use any other model of Atwater Kent speaker with Model 55, than the type F-4 or F-4C. Do not remove speaker plug from socket when set is in operation. The set should be operated with the local distance switch in the local position when receiving nearby stations. Failure to do this may result in overloading of the detector tube, which will be evidenced by a decrease of output volume at the resonant point on the tuning dial, as well as a slight ragged type of distortion on strong stations.

FIG. 7,333—Text continued.

moved toward the extreme "low" position, the choke and condenser both become effective, and thus reduce the high frequency output of the receiver. The amount of this reduction is dependent on the position of the potentiometer arm, operated by the tone control knob.

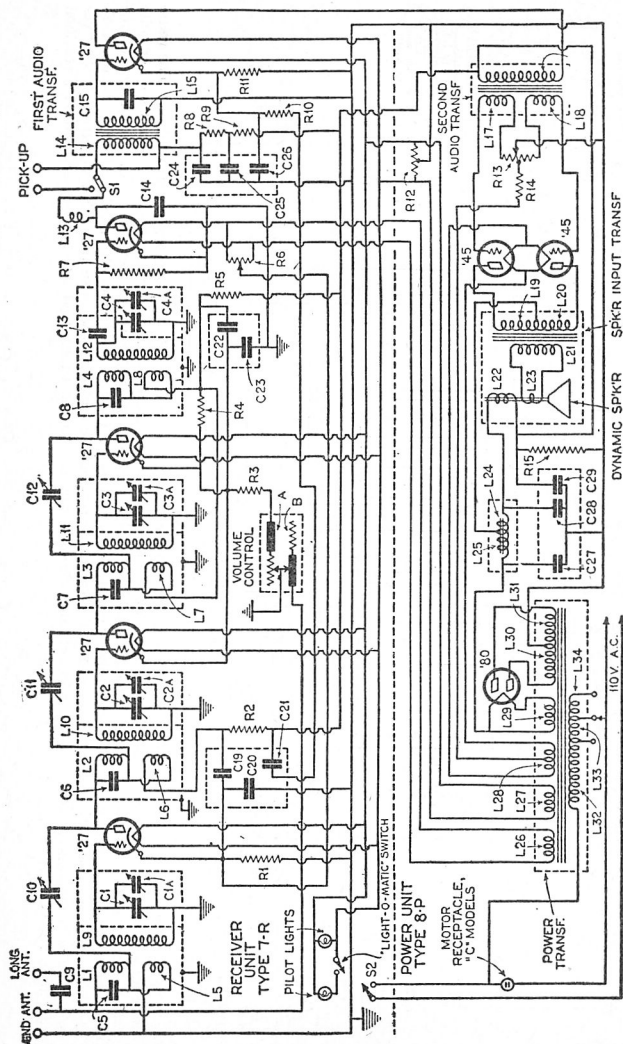


FIG. 7.337.—Wiring diagram of Edison R-4, R-5 and C-4 receivers. L1, L2, L3 and L4 are low frequency primaries, resonated to approximately 450 kilocycles by means of the condensers C5, C6, C7 and C8; L5, L6, L7 and L8 are high frequency primaries, not shunted by any condenser; L9, L10, L11 and L12 are secondaries tuned by the variable condenser sections C1, C2, C3 and C4, which are shunted by the trimming capacitors C1A, C2A, C3A and C4A. Stabilization of the r.f. amplifier is accomplished by the use of grid circuit neutralization; that is, the employment of neutralizing condensers, C10, C11 and C12 connected from the plate of each r.f. amplifying tube to a coil tightly coupled to the secondary of the input transformer of that tube. These coils in the diagram are L5, L6 and L7, which are at the same time the high frequency primaries of the

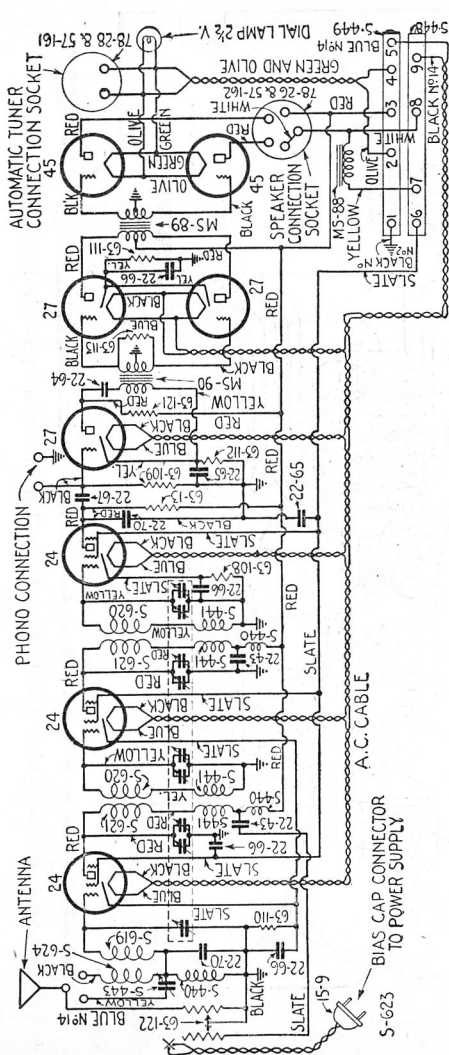


FIG. 7.338.—Circuit diagram of Zenith "70" series *a.c.* receiver. *The circuit consists of* two stages of tuned plate, tuned grid, screen grid radio frequency amplification, a screen grid power detector, one stage of resistance coupled audio amplification using a 27 tube, a second stage of push pull using two 27 tubes, and a third or power stage using two 45's in push pull. The electrolytic condenser, the voltage divider and the by-pass condenser for the grid bias of the third stage audio are placed in the power unit. The separate unit type condensers have been incorporated in this pack. A cover has been placed over both the terminal strips on the chassis and the fuse clip on the power pack. All possible wiring has been cabled. All cabled wire has a definite color code. The double volume control has been adopted as standard. Provision has been made to use a short aerial.

FIG. 7,337.—Text continued.

first, second and third τf transformers. Substantial resonance of the first τf input circuit to the resonant frequency of the second and third τf and detector input circuits is maintained by holding the effective aerial-ground capacity to a value less than 100 micromicrofarads. Self bias of the first τf amplifying tube is secured by the use of resistor R1, by-passed by the capacity C20. Isolation of the τf component of the plate current of this tube is accomplished by the use of resistor R2, and capacity C19. Self bias of the second and third τf amplifying tubes in common is effected by the resistor R3, and the section A, of the volume control by-passed by the capacity C23. Isolation of the τf components of the plate currents of those two tubes in common results from the use of the resistor R5 and the capacity C22.

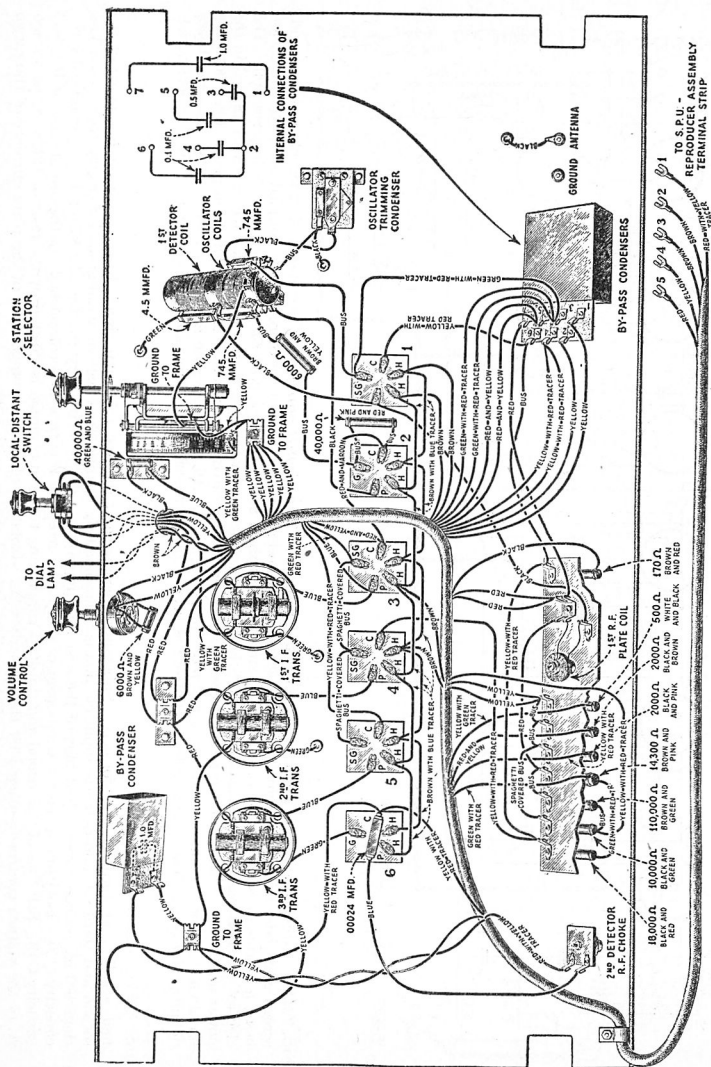


FIG. 7,339.—Pictorial wiring diagram of General Electric Model H 31 screen grid super-heterodyne receiver.

CHAPTER 178

Short Waves

Short waves permit broadcasting to much greater distances than with the longer waves regularly used, and in order to extend the broadcasting range some of the leading stations simultaneously transmit their programs on long and short waves.

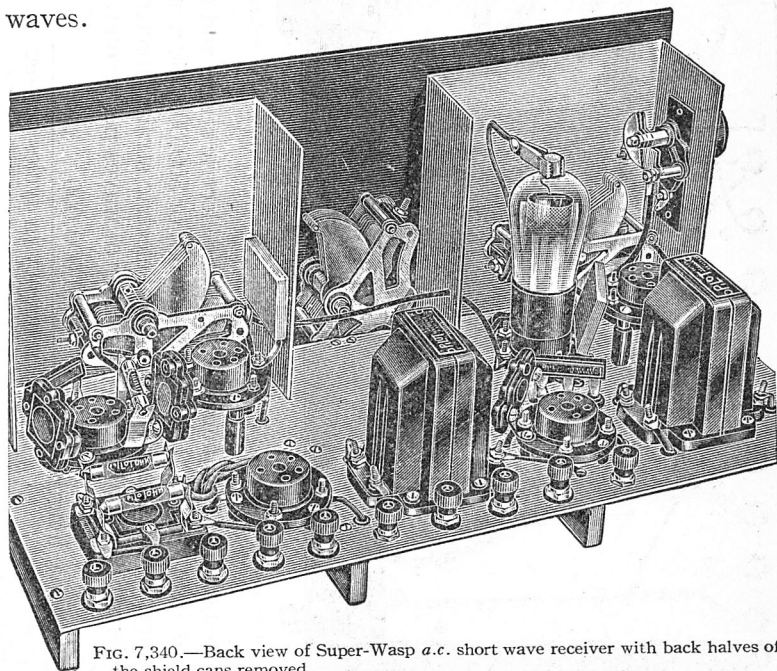


FIG. 7,340.—Back view of Super-Wasp a.c. short wave receiver with back halves of the shield cans removed.

By definition, a short wave is *any wave of a length less than 200 meters.*

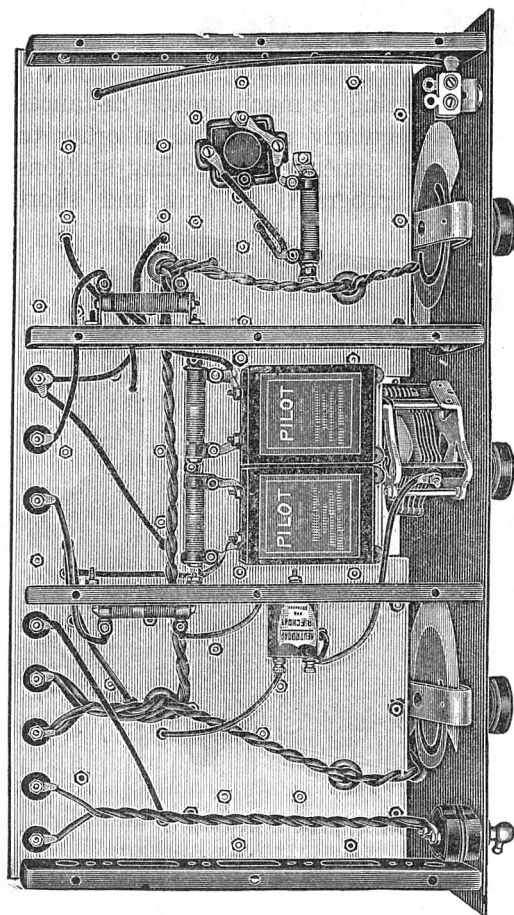


FIG. 7,341.—Under view of Super-Wasp a.c. short wave receiver showing arrangement of parts.

Wave Length and Frequency.—Since the electric strain and flux lines move with the velocity of light, 186,300 miles per second, or 300,000,000 meters per second, the distance between two successive maxima of electric strain directed in the same direction, or, wave length = $300,000,000 \div \text{number of waves per second}$. As usually expressed,

$$\text{wave length} = \frac{300,000,000}{\text{wave frequency in cycles per sec.}} \dots\dots\dots (1)$$

From the formula it is seen that *the shorter the wave length the higher the frequency.*

Examples.—What are the frequencies for wave lengths of 10 and 200 meters? From formula 1

$$\text{wave frequency} = \frac{300,000,000}{\text{wave length}} \dots \dots \dots (2)$$

substituting 10 in formula 2

$$\text{wave frequency} = \frac{300,000,000}{10} = 30,000,000 \text{ cycles or } 30,000 \text{ kilocycles}$$

substituting 200 in formula 2

$$\text{wave frequency} = \frac{300,000,000}{200} = 1,500,000 \text{ cycles or } 1,500 \text{ kilocycles}$$

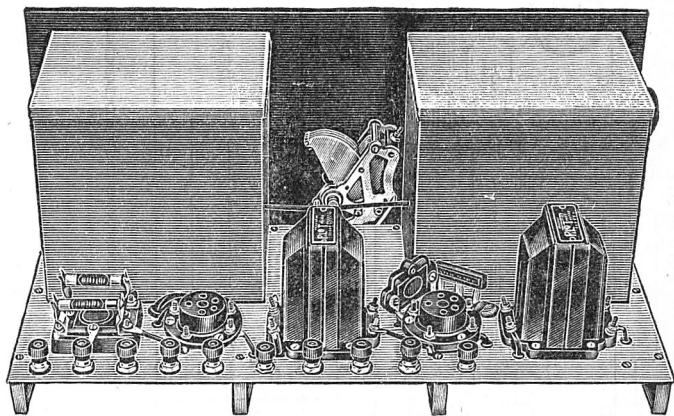


FIG. 7,342.—Back view of completed Super-Wasp a.c. short wave receiver showing shield cans in place.

that is, for a 10 meter wave, the frequency is $(30,000 \div 1,500)$ or 20 greater than for a 200 meter wave.

High Frequency Reception.—The requirements of receivers for short waves are different than for ordinary receivers on account of the high frequency of the short waves.

With short waves the inductance and capacity effects between wires and coils are very marked.

All wires from grids and plates of tubes should be kept short and well separated. Unless care be exercised in wiring the variable condensers, troublesome hand capacity effects are liable to result. This makes tuning very difficult, and is manifested by a change in the tuning of the set whenever the hand is brought near the tuning dial.

The wire from the grid of the tube to the tuning coil and condenser should always be connected to the stator plates of the tuning condenser, and the rotor plates should go to the grid return circuit.

Complex circuits using multi-stage amplifiers are usually either unstable or have too many operating controls to be of value.

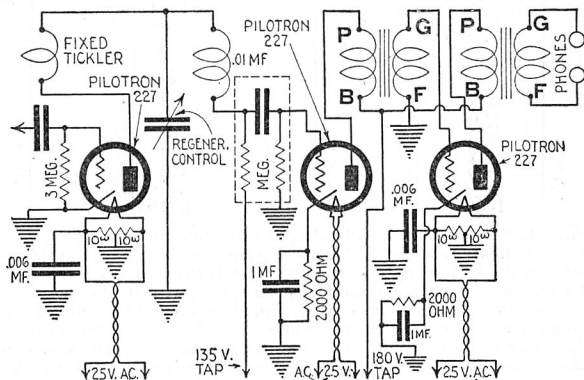
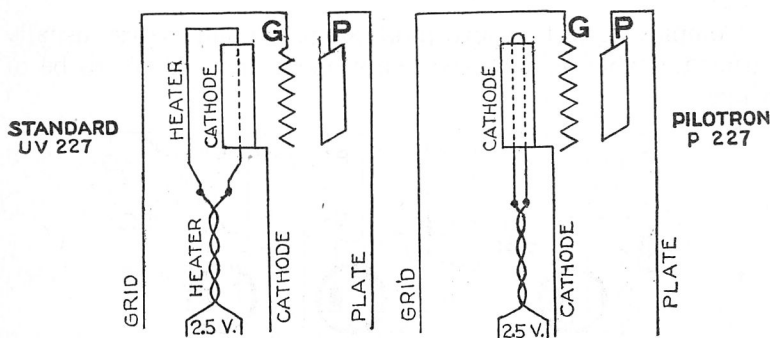


FIG. 7,344.—Audio amplifier system of Super-Wasp a.c. short wave receiver. The first stage is resistance coupled, the second stage transformer coupled. The amplification system consists of a detector working directly into a high resistance high capacity coupling unit, onto the grid of the first audio tube. This audio stage is then coupled to the last audio tube through a standard transformer with the primary phase arranged for negative howl tendency. A tube with the standard electrical amplification characteristics of the 227 is used in all three positions. The use of this first resistance stage reduced the residual hum much more than the reduction in audio amplification. It was found that a net gain in hum reduction resulted from the use of the resistance coupling in the first stage. The resistance units did not act like a.c. pick up coils, as did the transformer windings in this location.

Short Wave Receivers.—These usually consist of a stage of radio frequency amplification followed by a regenerative detector, either with or without one or two stages of ordinary transformer coupled audio frequency amplification. The use of a

stage of tuned screen grid radio frequency amplification increases the sensitivity greatly.

The nature of the power supply and of the audio amplifier system is of little consideration. The success of the receiver depends mostly upon the apparatus that precedes the audio amplifier.



FIGS. 7,345 and 7,346.—Modification of tubes to avoid hum in Super-Wasp *a.c.* short wave receiver. In the ordinary tube, fig. 7,345, it is apparent that at one instant the bottom of the filament will be positive while the top is negative, shortly followed by a reversal of the heating current which makes the bottom of the filament negative with the top positive. The electronic field within the cathode is thus rapidly twisted back and forth during each alternation of the heating current. A noticeable hum results. Now the construction shown in fig. 7,346 is purposely designed to avoid this. The heating filament is doubled back on itself within the cathode cylinder after the fashion of a hairpin. In this arrangement, the electronic field is neutralized at every point and no upheavals take place on the reversals of the heating current.

Most owners of short wave receivers do not fully appreciate the fact that the entire success of their outfits depends on how smoothly and easily they can control the regenerative action of the detector tube.

Many carefully built receivers using the most expensive parts do not produce more than a few weak local broadcasting stations and possibly a dozen loud telegraph stations, simply because the detectors collapse into oscillation with a pronounced "plop."

Many carelessly assembled sets using parts retrieved from the junk box bring in phone stations from all over the world, because the regenerative action has precision control.

On account of the very great difference in frequency in the range of short waves it would not be practical to provide a tuning system for the full range that would be satisfactory, hence the receiver is designed for the particular *wave band* desired or is provided with removable coils, called plug in coils, or condensers or both.

These can be changed for each of the many narrow wave bands into which popular short wave transmission is now divided. These are, the

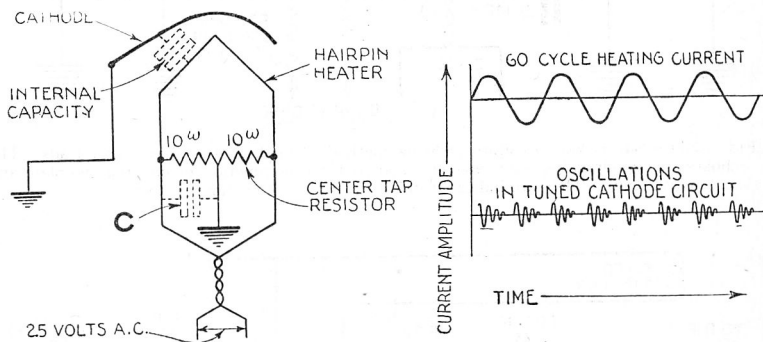


FIG. 7,347.—Method used in Super-Wasp *a.c.* short wave receiver to kill the little oscillating circuits in the tube circuit by addition of a by-pass condenser C. The capacity of the oscillating system is the internal capacity of the cathode-heater combination. The inductance is that of the leads combined with that of the center-tapped resistance. This resistance unit actually has enough inductance to be troublesome at the very short waves. The cure consists in merely adding a .006 *m.f.* condenser across one side of this center tapped inductance, so as to kill the resonant combination.

FIG. 7,343.—Diagram showing how 60 cycle *a.c.* creates oscillation in the tuned cathode circuit of Super-Wasp *a.c.* short wave receiver.

160 meter, 80 meter, 40 meter and 20 meter amateur bands and the broadcast short wave bands at 50, 25 and 20 meters. Most short wave sets are now built with a non-removable variable tuning condenser and a number of removable plug in coils which are wound for tuning to the various wave bands.

Simplest Short Wave Receiver.—In building any short wave receiver it is important to consider problems which, in the ordinary broadcast band from 550 to 1,500 kilo cycles were

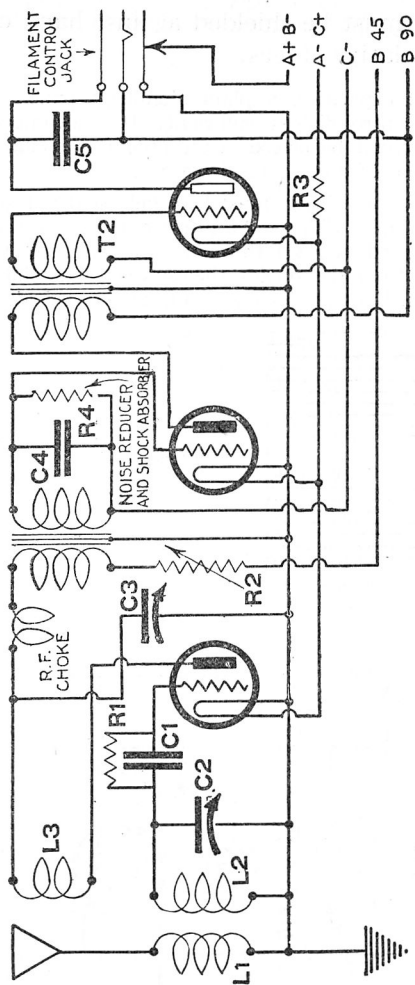


FIG. 7,351.—Typical hook-up of a good regenerative short wave receiver.

considered relatively unimportant; to see that the capacities of the coil windings themselves be carefully kept down at all times.

The minimum capacity of the condenser is important; so it is imperative under such conditions to use the appropriate type of variable condenser.

The grid and plate capacities of the tube also play an important part, and it is, therefore, essential that the grid and plate leads shall be as short as possible, and as far away from one another as they can be placed. Moreover, the radio frequency currents *must* be confined to those circuits in which they belong. Blocking condensers should be used profusely but intelligently. It must be borne in mind that these by-pass or coupling condensers should have as little leakage as possible, in order to conserve the weak radio frequency current.

NOTE.—The short wave radio set builder can obtain the necessary parts for building the short wave Super-Wasp set from the manufacturer, The Pilot Radio and Tube Corp., Brooklyn, N. Y.

The short wave receiver must be shielded against hand capacities and between the relative stages.

For shielding against hand capacities, a plain aluminum panel, for mounting the condensers and control dials, is sufficient. It is not imperative that the balance of the circuit be placed in an aluminum container although it is quite advantageous for mechanical reasons.

In the case of copper shields, the corners must be evenly soldered; aluminum should have large overlaps. Short wave interference unless these precautions are carefully observed, will get through. The coils must be kept as far away as possible from the shields themselves. The shields should not be of thin material, but of a thickness sufficient to shield one

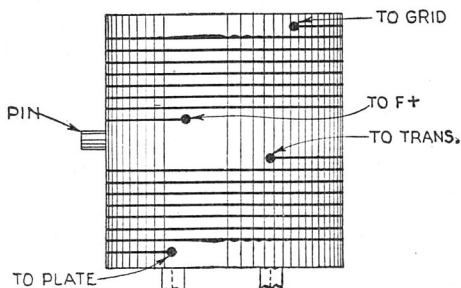


FIG. 7,352.—How plug in coils are made.

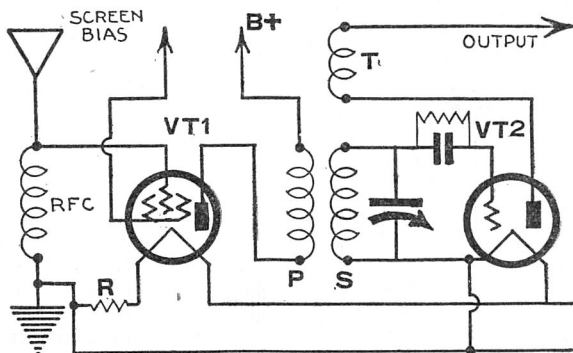


FIG. 7,353.—Connection of radio frequency stage with screen grid tube, ahead of regenerative detector.

stage effectively from the other. With copper, a thickness of 30 mils (.03 in.) seems to be quite reasonable. In the case of aluminum, a thicker or substantial piece of metal should be used, with an overlap of half an inch wherever possible.

A very simple diagram showing a single control super-heterodyne, is fig. 7,353.

The output circuit is from the filament of VT2, and the output. The secondary of the three circuit arrangement is made to oscillate at a frequency differing from that of the incoming wave by a value corresponding to the frequency of the intermediate stage. If the intermediate stage be a broadcast receiver tuned to 1,000 kilocycles, the difference between the oscillator frequency and that of the incoming wave should be 1,000 kilocycles.

Short Wave Receiver Reference Table

- C1—.0001 mf. mica fixed condenser.
- C2—.000015 mf. midget variable condenser, 7 plate.
- C3—.000015 mf. midget variable condenser, 7 plate.
- C4—.0005 mf. mica fixed condenser.
- C5—.0005 mf. mica fixed condenser.
- R1—10 megohm grid leak (noiseless).
- R2—0-50,000 ohm Bradleyohm.
- R3—Rheostat or amperite.
- R4—1/10 megohm grid leak.
- L1—Two turns bell wire around coil socket base.
- L2—Grid coil on plug in tube base.
- L3—Tickler on plug in tube base.

Wave Band	L2		L3	
	Turns	Wire Gauge	Turns	Wire Gauge
80	37	28	25	30
40	16	22	20	30
20	7	22	10	30
10	3	20	5	30
5	1	20	3	30

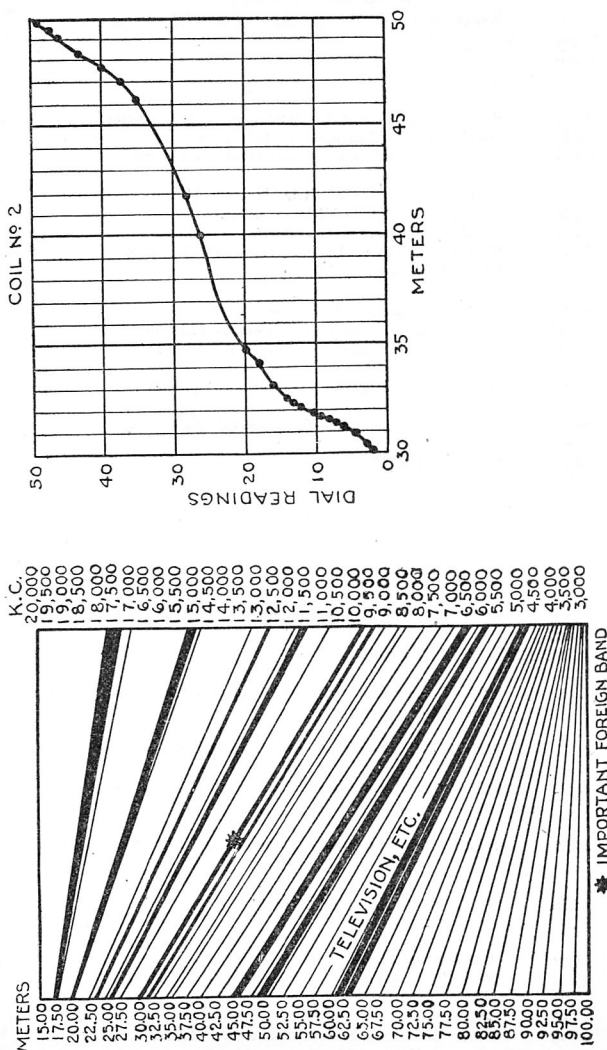
How to Tune Short Wave Receivers.—The short wave beginner is usually surprised to begin picking up broadcast stations which he cannot find in the short wave list. What he hears is the *harmonics* of stations broadcasting on the medium waves between 200 and 550 meters. These are often a nuisance, for they may be poorly modulated, and they are easily mistaken for a foreign station, and sometimes they interfere with wanted foreign stations. The last named trouble is one which will have to be dealt with as short wave broadcasting becomes more general; but at the present time the experimenter will find these harmonics useful for the calibration of the dials.

Each harmonic has a definite wave, just as much so as the broadcast station's fundamental carrier wave. A harmonic must have exactly twice, three times, five times, nine times, etc., the frequency of the fundamental (corresponding respectively to $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{5}$, $\frac{1}{9}$, and so on) wave length. Many of these harmonics can be heard with any short wave receiver. When one of them is picked up, and the station identified, it is only a matter of division to determine the exact wave to which the receiver is tuned. By checking up a number of these harmonics, and the few known short wave broadcasters, it is a very simple matter to draw up a calibration curve for each coil of any short wave set.

Take a sheet of paper for each coil, and number each from top to bottom with figures corresponding to those on the tuning dial or dials, usually 0 to 100. (These numbers do not correspond to the settings of the regeneration dial.)

Start with any one, or pair, of the coils covering a certain wave band; and tune in the first station picked up. If it be a regular short wave station, mark down its known wave exactly opposite the figure on the chart which corresponds to the dial setting. If the station be one which is not known to have a short wave transmitter, then a harmonic has been heard.

Look up the authorized wave length of the station and divide it by the number which will bring the result nearest to the wave length to which the coil should be tuned. For example, if the coil be rated by the manufacturer as covering from 30 to 55 meters, and the condenser setting is low, then it is probable that the wave length must be between 30 and 40 meters.



COIL No. TWO

Range 30 to 55 Meters (Approximately)

Dial Reading	Wave- length	Stations Heard
0		
1		
2	30.01	WRVA (9th Harmonic—fundamental 270.1 meters)
3	30.50	NRH, Heredia, Costa Rica, 10-11 p. m. daily
4	30.85	WBT (9th Harmonic—fundamental 277.6 meters)
—5		
6	31.04	KQV (7th Harmonic) 7LO, Nairobi 11-2 p. m. daily
7	31.26	W3XAU — PCJ — VPD — KJXR
8	31.38	Konigswusterhausen (Berlin) Germany
9	31.48	W2XAF — OXY, Lyngby, Denmark, 2-3 p. m.
—10	31.80	XDA, Mexico City, Mexico
11		
12	32.10	CGA, Drummondville, Canada
13	32.20	WSAI (7th Harmonic—fundamental 225.4 meters)
14	32.40	GBK, Rugby, England (transatlantic phone)
—15		
16	33.26	GBS, Rugby, England (transatlantic phone)
17		
18	34.23	KSTP (6th Harmonic—fundamental 205.4 meters)
19		
—20	34.68	W2XAC, HKCJ
21		
22		
23		
24		
—25		
26	40.00	WWRL (5th Harmonic—fundamental 199.9 meters)
27		
28	41.80	KSTP (5th Harmonic—fundamental 205.4 meters)
29		
—30		AMATEUR PHONE BAND
31		
32		VRY, Georgetown, British Guiana (Wed. and Sun., 7:15-9 p. m.)
33		Code (Mobile services)
34		
—35	46.12	WHAP (5th Harmonic—fundamental 230.6 meters)
36		
37	46.92	WOR (9th Harmonic—fundamental 422.3 meters)
38		
39		
—40	47.59	WLBL (7th Harmonic—fundamental 333.1 meters)
41		
42		
43	48.35	HKT, Bogota, Columbia, 10-11:30 p. m.
44		
—45		
46	49.02	W2XE, New York
47	49.40	W8XAL, Cincinnati
48		
49	49.80	W9XF
—50	49.98	HRB, Honduras, Mon., Wed., Fri., 9-12 p. m.

If the station heard be working on a fundamental of 274.9 meters (1,080 kilocycles) it will be seen that dividing this by nine gives 30.54 meters (9.720 kilocycles) and this is the wave length of the ninth harmonic, which is being heard.

The odd harmonics are usually of much greater strength than the even harmonics.

Mark the wave length found, 30.54, on the proper sheet opposite the condenser dial reading. It is necessary to carry the wave length out to two places; for a tenth of a meter covers considerable room on a short wave dial.

Go up slightly on the dial and find a harmonic of a broadcast station which is known to be working on 215.7 meters (1,390 kilocycles). Since the seventh harmonic of this station is 30.81 meters (7,730 kilocycles) set down this figure opposite the second dial reading. In this manner, the dial is calibrated from top to bottom on the chart; calibrate the other coils in a similar way until it is determined where any given wave may be tuned in on the receiver. Stations may thus be found right where they should be expected.

Tuning Problems.—The great sharpness of tuning on short waves should be considered; compare it with the broadcast band. In the United States and Canada exactly 96 broadcast channels are in use, one every ten kilocycles from 550 to 1,500 kilocycles inclusive. This gives one channel to a division on the dial, and each station therefore corresponds to a different reading.

It is not necessary to discuss the relation of kilocycles to meters here (see fig. 7,354) except to say that the frequency increases more and more rapidly as the wave length becomes shorter. Between 15 and 80 meters (the effective short wave broadcast band) there is more than 1,600 kilocycles separation, or sixteen times the width of the upper broadcast band. The average short wave set covers this with three or perhaps four coils and as many revolutions of the tuning dial, from 0 to 100.

If stations were operated on channels 10 kilocycles wide, as in ordinary broadcasting, 300 to 400 of them would be covered in one turn of the dial. On the smaller coils, the number is even greater. The station, therefore, covers only a small part of the space between two numbers on the dial.

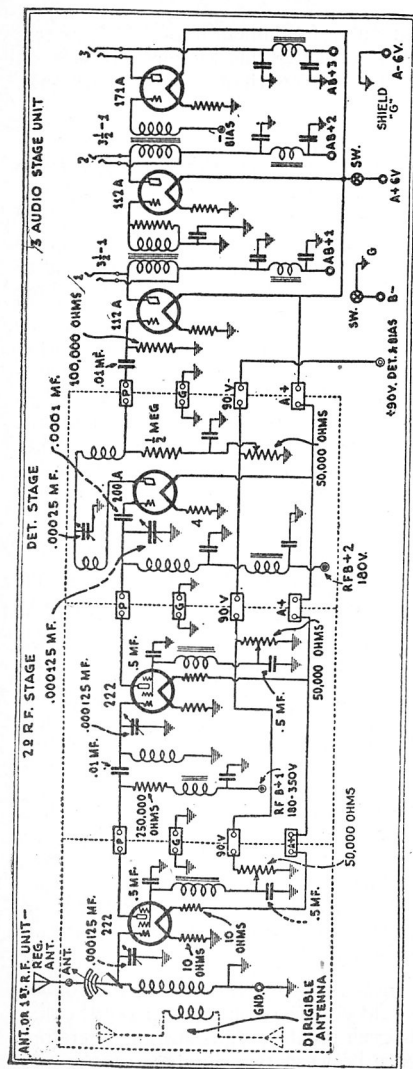


FIG. 7.356.—Wiring diagram of Leutz short wave receiver. It is of the unit construction giving a flexible arrangement and providing double shielding. For example, if desired, the detector unit and audio unit would be used together as a complete receiver. To that combination, one tuned radio stage can be added and later still another tuned radio stage added again. For average purposes the following set up is suggested, one tuned radio stage, detector stage and audio unit. For extreme distance work and where maximum volume is desired, the full combination is required consisting of first radio stage, second radio stage, detector stage and audio unit. Due to obvious technical limitations, the power output stage of the audio unit is not push pull. Two power tubes in push pull combination require a certain high signal input voltage in order to secure full output. The required signal voltage is not always available on short wave signals in which case the complete signal would be entirely lost. By having three cascade stages of audio amplification, sufficient volume is still available and the amplifier is sensitive even to the very weak signals. The detector unit is arranged to use any of the standard superdetector tubes such as the 200A, 240, etc. The tuned inductance has two windings, one for the detector grid circuit and the other for the plate regenerative amplification circuit, the coupling between the two being fixed. For the first $r.f.$ one stage unit tuned inductance is required and it has two windings. The first winding tunes the grid circuit of the tube which is capacitively coupled to the antenna circuit. The second winding may or may not be used as desired. It is provided to enable using a dirigible type aerial and suitable binding posts are provided to connect such an antenna. For maximum sensitivity a second tuned radio stage should be added. In the Leutz short wave set, this stage is added by connecting same between the antenna stage and detector stage. No internal connections need be disturbed. In all the tuned stages, vernier condenser adjustments are provided where required. Individual filament resistors are also available so that each tube can be regulated to its maximum operating point of efficiency.

If the dials be operated in the manner usual in medium wave tuning, many *noises* will be passed over, which are really stations that would give good loud speaker strength if properly tuned in. The proper procedure, therefore, in operating a short wave set, is to calibrate the receiver in the method illustrated, and make notations where certain desired stations should fall on the dials. Note when these stations may be expected to operate; and tune for them at the proper times, on the proper dial readings.

Pick up the signals by the *beat note* method; that is, set the detector tube oscillating, and pick up the carrier wave, or *squeal*. After the carrier is found, keep the wave length or tuning dial set in the exact center of the squeal; and turn the regeneration dial back past the point of oscillation. Then, very slowly, move it up again until the best reception is obtained.

The third point is how to determine what stations to tune for.

At the present time, all short wave broadcast stations are of an experimental nature, and their wave lengths, as well as schedules, are subject to sudden changes without notice. Since distance means little or nothing in short wave reception, the carrier wave in its longer path is more subject to atmospheric conditions than the nearby medium wave broadcasts.

Stations which can be heard with great volume at one season of the year are often unheard at another, regardless of the power which they use. The short waves, also, are peculiarly affected by sunlight; some being reduced in strength, and others greatly increased in volume on the arrival of darkness. Since reception is world wide, means of communication are slow, and no universal language is yet in use, no accurate list of stations can be compiled.

It may be said that reception of short wave broadcasts directly from overseas is not so difficult as may be imagined; it is a commonplace occurrence.

It is possible to pick up programs in Siamese, Russian, German, Spanish, French and many other languages, in addition to English.

TEST QUESTIONS

1. What is a short wave?
2. What is the advantage of short waves?
3. Explain the relation between wave length and frequency.
4. Give formula for wave length.
5. How does the frequency vary for the different wave lengths?
6. What are the requirements of sets for highest frequency reception?
7. What makes tuning difficult when the hand is brought near the tuning dial?
8. Of what does a short wave receiver usually consist?
9. Upon what does the success of the receiver mostly depend?
10. Why is tuning difficult on some short wave receivers?
11. What is a wave band?
12. Explain why "plug in" coils are used?
13. How are most short wave sets usually built?
14. Give directions for building a simple short wave receiver.
15. Draw a diagram of a single control super-heterodyne set.

CHAPTER 179

Aerials

By definition an aerial is *a wire system suspended in the air and insulated at the ends for receiving electro-magnetic waves.*

Strictly speaking an *aerial* is the wire system at the receiving end as distinguished from an *antenna* or wire system at the transmitting end.

Aerials may be classified:

1. According to the number of wires as

- a. Single wire;
- b. Multi-wire.

2. According to location, as

- a. Outside;
- b. Inside;
- c. Underground.

3. According to shape, as

- a. Inverted L;
- b. Tee (T);
- c. Cage;
- d. Fan;
- e. Umbrella;
- f. Loop { solenoid, spiral,
pancake,

etc.

The simplest type of aerial consists of a single wire of suitable length with its ends connected to elevated insulators as in fig. 7,357.

At the end nearest the radio set a *lead in* connects the aerial to the set. This arrangement is known as an inverted L aerial; when connected at the center it is called a T aerial, the distinction being shown in figs. 7,358 and 7,359. Various other types of outside aerials are shown in figs. 7,360 to 7,369.

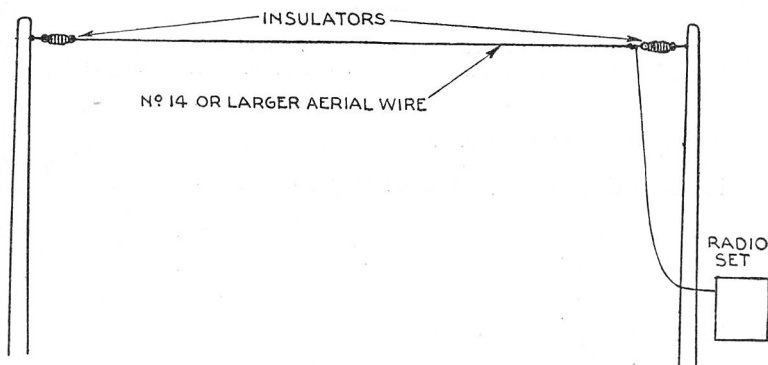
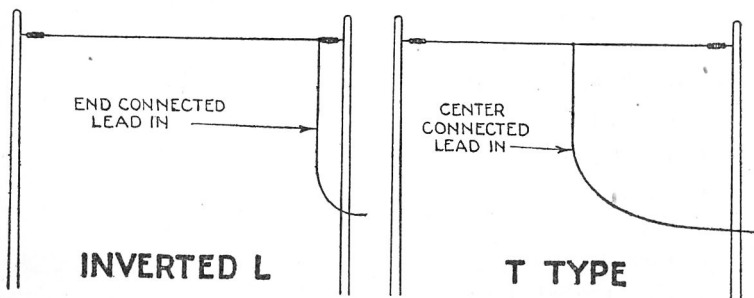


FIG. 7,357.—Single wire outside inverted L aerial; end connected lead in.



FIGS. 7,358 and 7,359.—Inverted L and T aerials. The lead in is usually connected at the end, but where an extra long aerial is desired it is connected at the center.

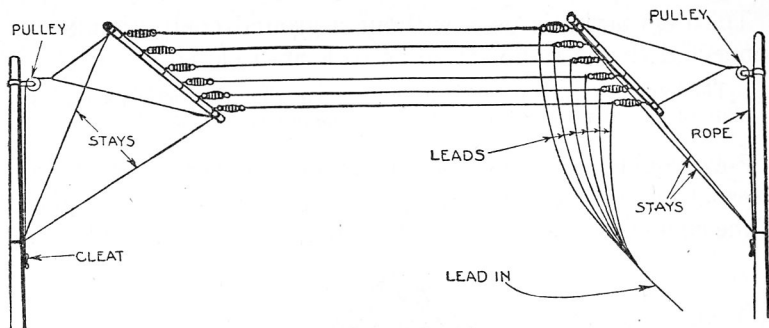


FIG. 7,360.—Multi-wire inverted L (flat top) outside aerial. Where the distance between supports is limited, the necessary length of aerial may be obtained by running two or more lengths of wire parallel as shown.

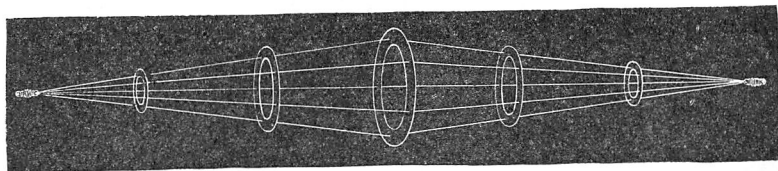


FIG. 7,361.—Cage antenna. A type frequently employed at transmitting stations.

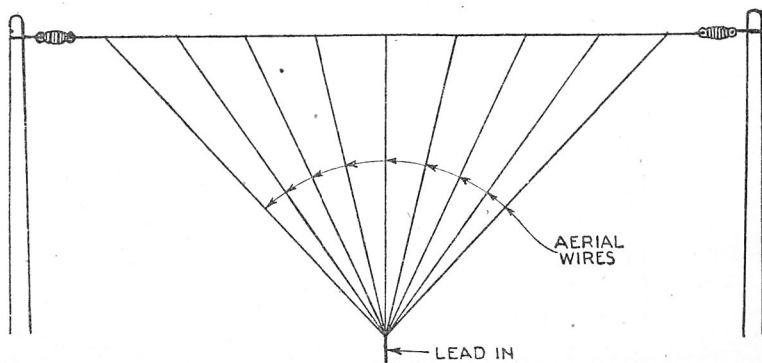


FIG. 7,362.—Fan aerial.

The loop aerial is used without a ground connection being connected to the radio set so as to form a closed circuit.

The loop acts as an inductance coil whereas the other aerials act as one plate of a condenser with the ground or *counterpoise* as the other.

Electro-magnetic waves on reaching the aerial set up an alternating voltage between the wires forming the upper plate of the condenser and the ground or lower plate of the condenser.

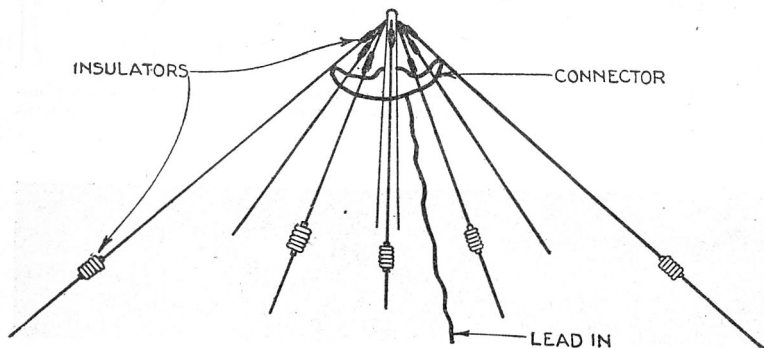


FIG. 7,363.—Umbrella aerial. The radial wires connect at the top with a vertical lead in.

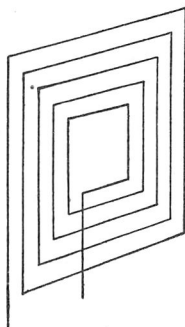
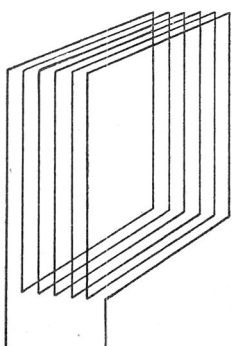


FIG. 7,364.—Inside loop aerial of the solenoid type.

FIG. 7,365.—Inside loop aerial of the pancake type.

This action takes place through electrostatic induction. In the *loop aerial*, electro-magnetic induction sets up an induced voltage thus causing alternating current to flow to the detector.

Counterpoise.—In places where it is difficult to obtain a good ground because of dry soil a *counterpoise* is used.

This consists of a second aerial suspended on supports about one foot above the ground and insulated from the latter. The counterpoise should run parallel with and preferably underneath the main aerial, though if necessary it may be offset to one side. Fig. 7,367 shows the essentials.

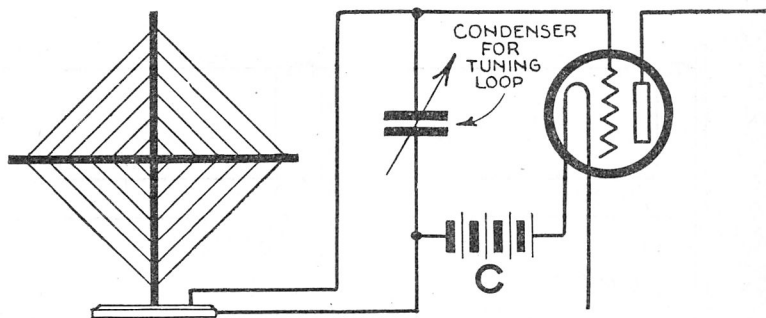


FIG. 7,366—Method of connecting a loop aerial. Since loop aerials are not very efficient, they should only be used with sensitive sets such as super-heterodyne.

Length of Aerial.—For best results make the aerial *as short as will permit reception from the desired stations*. A 30 foot wire is considered a short aerial.

In congested districts a short aerial should be used. The selectivity of the set depends largely on the length of aerial, some sets having two or more aerials of different lengths.

Location of Aerial.—The best location of the aerial *depends on local conditions*, each installation presenting its own problems.

In general when satisfactory reception is not obtained, the trouble may be rectified *by changing the direction of the aerial*; if possible place the aerial at right angles to its former position.

Installation.—Erect the aerial *as far from other wires as possible*.

The insulation should be of the best quality. The wire should be sufficiently taut to prevent undue vibration or swinging. Do not place an aerial under or above power wires; select a direction as nearly as possible at right angles to other wires.

There should be a good soldered connection of the lead in to the aerial.

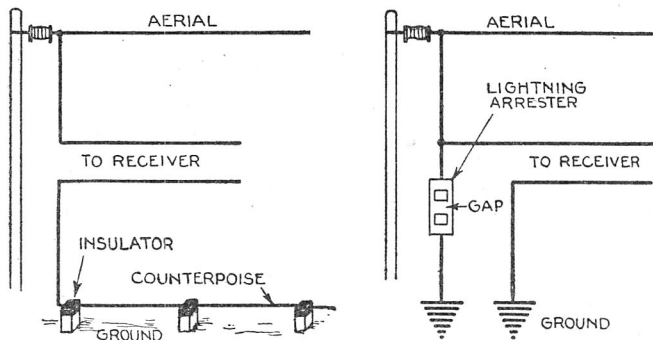


FIG. 7,367.—Counterpoise and connection. The counterpoise forms one plate of a condenser of which the main aerial is the other plate.

FIG. 7,368.—Method of connecting lightning arrester to aerial circuit.

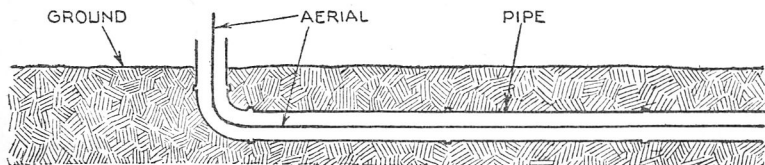


FIG. 7,369.—Rogers underground aerial. The aerial wire is placed inside a pipe. This type aerial is not affected much by conditions of the atmosphere.

Lightning Arrester.—The preferred location of the lightning arrester is *outside the building at the point where the lead in wire enters the building.*

One terminal of the arrester is connected to the aerial and the other to ground. The lightning arrester interposes a very small air gap between the aerial and the ground and across which any sudden high voltage impressed on the aerial as happens during a thunder storm will readily discharge across the gap without injuring the radio apparatus.

TEST QUESTIONS

1. *What is an aerial?*
2. *What is the difference between an aerial and an antenna?*
3. *Give classification of aerials.*
4. *Of what does the simplest type aerial consist?*
5. *What is the construction of a loop aerial?*
6. *What is the action of electro-magnetic waves on reaching the aerial?*
7. *What causes alternating current to flow in an aerial to the detector?*
8. *What is a counterpoise?*
9. *How should a counterpoise be run with respect to aerials?*
10. *What should be the length of an aerial for best results?*
11. *How long should an aerial be in congested districts?*
12. *Upon what does the selectivity of a set largely depend?*
13. *How is the best location of an aerial determined?*
14. *In what direction should an aerial be run?*

15. *How should an aerial be located with respect to other wires?*
16. *Why should an aerial be strung taut?*
17. *How should the lead in be connected to the aerial?*
18. *What is the preferred location for the lightning arrester?*
19. *How is the lightning arrester connected?*
20. *What does a lightning arrester interpose in the circuit?*
21. *Where does the air gap circuit terminate?*
22. *What happens in a thunderstorm?*
23. *Explain the operation of the lightning arrester.*

CHAPTER 180

Loud Speakers

By definition a loud speaker is *a device designed to convert the amplified audio frequency currents into sound waves*. In other words a loud speaker *changes varying electric currents into sound waves*.

In order to do this the construction of the loud speaker must be such that it will cause the varying electric currents to set in vibration a diaphragm similar to that used in a telephone receiver only larger.

The vibration of the diaphragm sets into vibration a large volume of air which produces the sound.

The efficiency of a loud speaker depends on how near these sound waves approach a true reproduction of the sound waves broadcast at the transmitting station.

It is hardly necessary to state that the efficiency of most loud speakers is very low and even that of the best is far from perfect.

Classification of Speakers.—That part of a loud speaker which changes the varying currents of the audio frequency amplifier into mechanical vibrations, is called the *driving unit* or *motor*, and with respect to the principle involved in the operation of the driving unit, speakers may be classed as:

1. Magnetic;
2. Balanced armature;
3. "Dynamic" or moving coil;
4. Induction;

5. Metal strip;
6. Electro-static or condenser;
7. Piezo-electric.

Speakers which use a permanent magnet are called *magnetic* speakers; those using an electro-magnet are generally known as *dynamic* speakers.

Magnetic Speakers.—In this type a *bipolar permanent magnet is used*. On each pole of the magnet is mounted a coil of

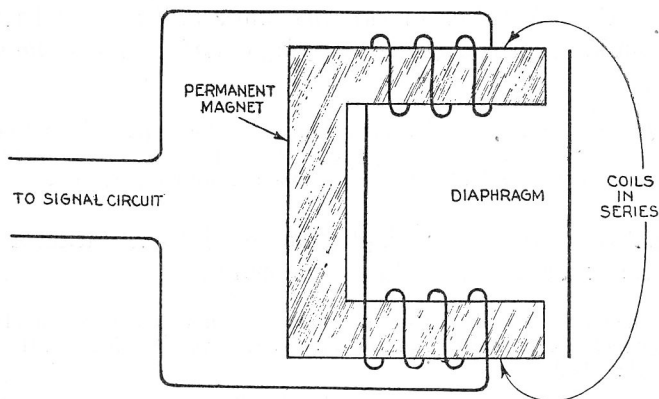


FIG. 7,370.—Magnetic type speaker consisting of a combined permanent and electro-magnet and diaphragm. The latter is of magnetic metal and the magnetic lines of force pass through it from pole to pole. If the diaphragm become saturated it will *not* respond perfectly to variations of the magnetic strength and *distortion* will result.

wire having a large number of turns, the two coils being connected in series, as shown in fig. 7,370.

The speaker is connected as indicated and in operation the varying currents coming from the plate circuit of the last tube varies the resultant magnetization (of coils and permanent magnets) accordingly causing the diaphragm to vibrate and produce sound waves.

Balanced Armature Speaker.—This speaker does not chatter easily on loud signals and responds well to weak signals. The

essentials of construction are shown in fig. 7,371. It has an armature pivoted at its center between the poles of a permanent magnet and provided with a coil through which the signal current flows as shown, so that the reaction between the magnetic field due to this current and that due to the permanent magnet causes the armature to oscillate about its pivot. These movements of the armature are communicated to the diaphragm by means of the link connection.

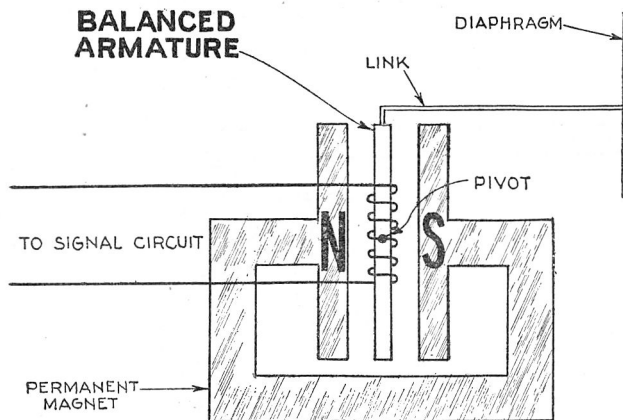


FIG. 7,371.—Balanced armature type speaker. *In construction* the balanced pivoted armature is a soft iron bar forming a core of a coil of several thousand turns of fine wire supplied with audio frequency currency. *In operation* when a signal current flows through the coil, a magnetic field is produced, which magnetizes the soft iron armature. The poles react on the poles of the permanent magnet and attraction between the unlike poles and repulsion between the like poles take place. With the polarities shown, the top end of the armature would move to the left and the bottom end to the right when the signal current flows through the coil in the corresponding direction. The amount of pull or movement is proportional to the current flowing through the coil, so the armature moves in accordance with the variations in the current.

Dynamic Speakers.—The *moving coil principle* is here employed. In this arrangement the signal current flows through the moving coil which is placed around the middle pole of a three pole magnet and the reaction between the two causes

the moving coil to vibrate corresponding to variations of the signal current. The diaphragm being mechanically connected to the moving coil vibrates similarly. The essential elements are shown in fig. 7,372.

Induction Speakers.—The operation of this type speaker depends upon *the production of eddy currents in the diaphragm by a varying magnetic field.*

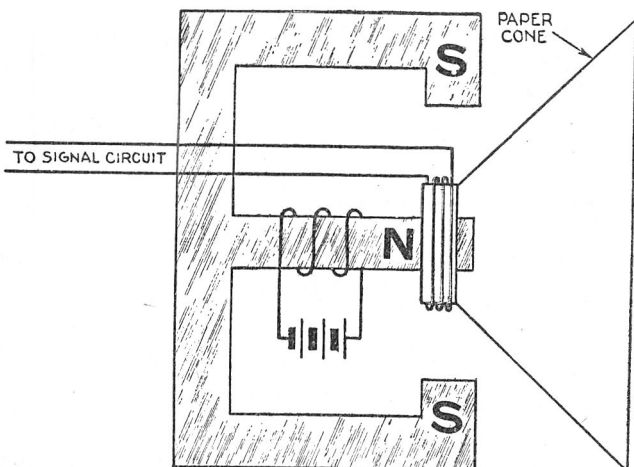


FIG. 7,372.—Dynamic or moving coil speaker. *In construction* the coil is very small and light. It vibrates between the armature magnetic field between two concentric magnetic poles. The coil is usually attached to a paper cone, or in the case of a horn to a non-magnetic diaphragm. The moving coil has about 100 turns of about No. 34 wire on a thin insulated shell.

As shown in fig. 7,373, the diaphragm is placed between two sets of concentric coils. Direct current is applied to the two sets of coils in opposite directions producing a radial field. The signal current is also passed through the coils which causes the steady field due to the *d.c.* to vary and which in turn induces eddy currents in the diaphragm.

Since the eddy currents give polarity to the faces of the diaphragm these poles react with the poles of the coils, thus causing vibration of the diaphragm and resulting sound waves. Loud speakers of this type are extra powerful and therefore suitable for halls.

Metal Strip Speaker.—This speaker is a type of the magnetic class in which *a metal strip is suspended between the poles of a permanent or electro-magnet and the signal current passed through the strip*, as shown in fig. 7,375.

The reaction between the steady field of the magnet and varying field of the strip causes the latter to vibrate. The metal strip being the diaphragm the sound waves are produced direct without any drive gear.

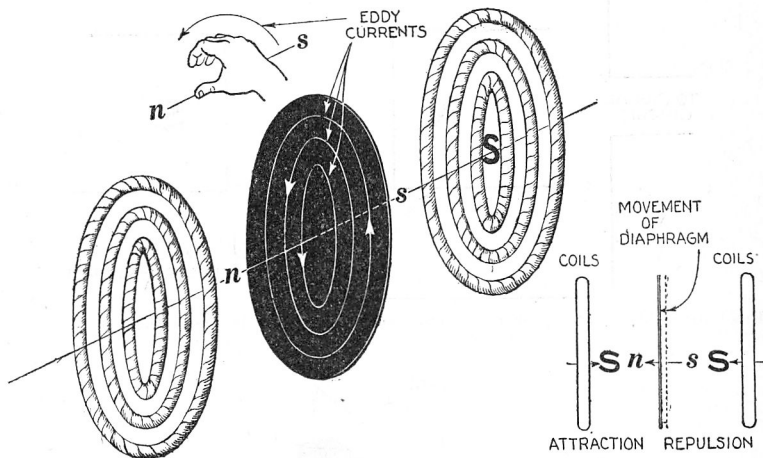


FIG. 7,373.—Induction speaker. In this speaker the diaphragm is made of a non-magnetic metal-aluminum. An auxiliary source of current is required to supply the steady magnetic field.

FIG. 7,374.—Side view of induction speaker. Since the *d.c.* supplied to the coils is passed through the two sets of coils in opposite directions like poles *SS*, will be produced on their sides facing the diaphragm and unlike poles *ns* on the faces of the diaphragm. These polarities are easily determined by the right hand rule as shown in fig. 7,373. At the instant shown the diaphragm is moved to the left by attraction due to unlike poles *S,n*, and repulsion due to like poles *sS*.

Electrostatic or Condenser Speakers.—Speakers of this type consist essentially of three elements:

1. Plate;
2. Dielectric;
3. Diaphragm.

The dielectric is placed between the plate and diaphragm and the assembly forms a condenser, as shown in fig. 7,376, hence the name. Its adaptation as a speaker is shown in fig. 7,377.

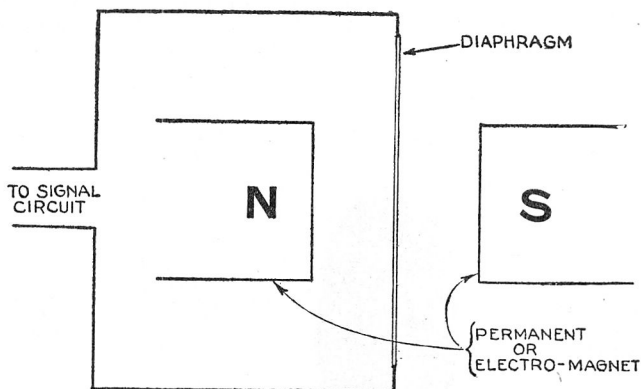


FIG. 7,375.—Metal strip speaker. A megaphone is used with this type speaker.

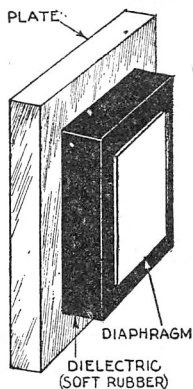


FIG. 7,376.—Elements of an electrostatic speaker. It is simply a form of condenser, hence the name as it is sometimes called a *condenser speaker*.

In the operation of a condenser any difference in voltage on the two metal elements (plate and diaphragm in fig. 7,374) produces attraction between them, thus compressing the dielectric which in this case is rubber. To keep the speaker normally in this condition, the plate and diaphragm are placed in a battery circuit. The signal current is superimposed on the battery current.

In operation the signal current varies the voltage in the circuit which in turn varies the attraction between the plate and condenser; the rubber which is in compression acts as a restoring force to displace the diaphragm

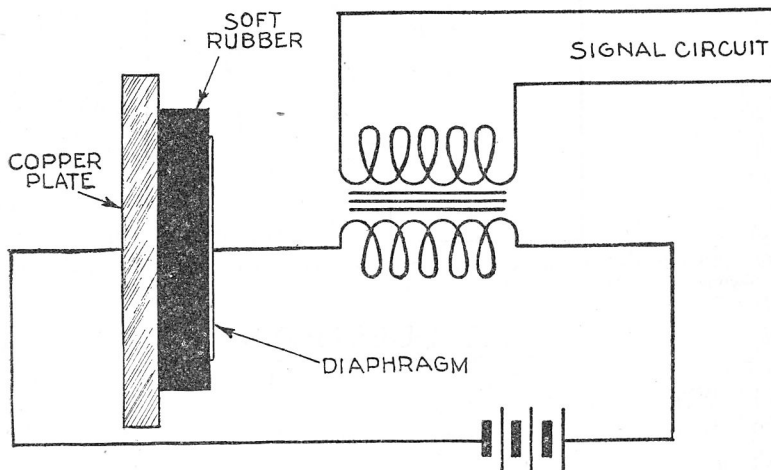


FIG. 7,377.—Electrostatic or condenser speaker showing circuit connections. *In construction*, the copper plate is made rigid. The diaphragm consists of a thin layer of metal sprayed on the rubber dielectric.

outward when the signal current is in such a direction as to reduce the attraction between the plate and diaphragm.

Piezo-electric Speakers.—This type of speaker depends for its action on *the property of a crystal of expanding and contracting in accordance with the electric strains to which it is subjected*. This principle as applied to a speaker is shown in the diagram fig. 7,378.

In operation the variations in the applied signal voltage will cause the crystal to expand and contract and these mechanical vibrations may by suitable means be communicated to a diaphragm.

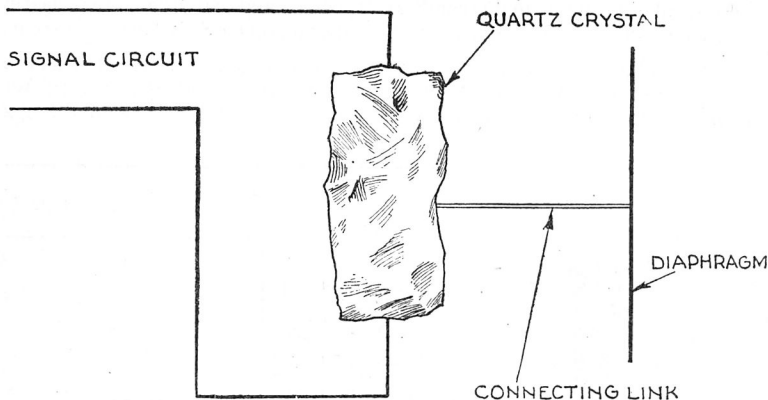


FIG. 7,378.—Piezo-electric speaker operating on the property of a crystal expanding and contracting with varying electric strains.

TEST QUESTIONS

1. What is a loud speaker?
2. How does a loud speaker work?
3. Give a classification of loud speakers.
4. How does a magnetic speaker work?
5. What is the construction of a balanced armature speaker?
6. Explain the operation of dynamic speakers.
7. What is the basic principle on which induction speakers operate?
8. Describe the metal strip speaker.
9. How does an electrostatic or condenser speaker operate?
10. Upon what does a piezo-electric speaker depend for its operation?

CHAPTER 181

Radio Instruments

For radio use, a volt meter should draw as small a current as is possible if it is to be left in circuit to show the voltage across the filament of a vacuum tube whenever it is in operation.

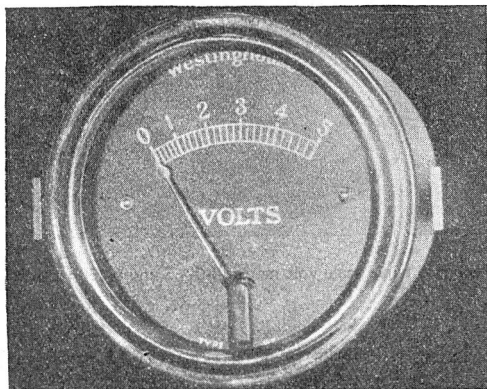


FIG. 7,379.—Westinghouse two inch diameter, 0-5 volt meter.

Unless the volt meter draw a small current, it cannot be placed across the vacuum tube filaments for the moment of adjustment of the rheostat, and then be removed from the circuit, without causing the filaments to have excessive voltage when the volt meter switch is opened.

Inefficient ammeters are undesirable for filament adjustment, since they have a relatively high voltage drop and the A battery must be replaced, or recharged, much sooner.

The most efficient polarized vane ammeters have a nearly complete circuit of non-residual iron in the form of a yoke with less residual magnetism than is found with instruments using merely a stubby core of less expensive iron. The result is a highly efficient instrument consuming only one tenth or even one fiftieth the energy required to operate other moving vane instruments.

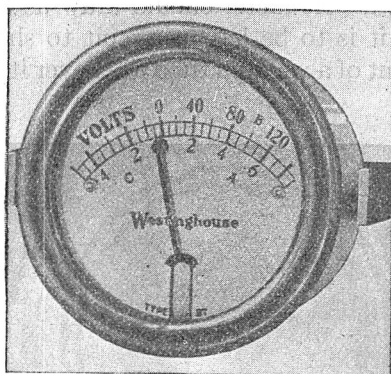


FIG. 7,380.—Westinghouse triple scale volt meter, 5-0-7.5 and 0-150 volts.

A vacuum tube set taking from three to five volts for filaments can be served better by a combination filament volt meter and plate battery tester than by a filament ammeter.

This combination instrument is more expensive than the ammeter, but it is worth more. Tungsten and tungsten alloy filaments can be adjusted better with a volt meter than with an ammeter because of the great change of resistance of that material and the corresponding slow change of current with a given change of applied voltage.

Volt Meter Combinations.—Several ranges of combination volt meters have been developed, which should cover the requirements of all radio sets.

They will indicate filament voltage and B battery voltage, and in some cases A battery and C battery voltage also. These have 100° scales. A triple scale volt meter is shown in fig. 7,380.

Switching Schemes.—Some switching device should be used to connect the volt meter across the different batteries one at

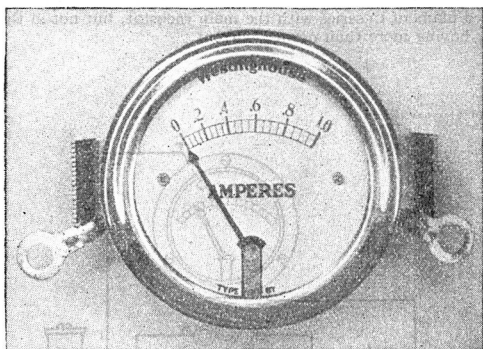


FIG. 7,381.—Westinghouse low loss ammeter, 0-1.0 amperes.

a time. There are a number of inexpensive dial switches on the market which are suitable for this purpose.

A switch should be chosen with sufficient movement of the blade so that adjacent active contacts will not be short circuited. If contact buttons be close together, then only every other contact should be used. Thus any five position switch could be used to show the voltage of three different circuits, such as filament volts, B battery volts, and C battery volts.

The high range requires an additional series resistance to reduce the higher voltage so that the instrument current is the same and will give the same deflection on 150 volts as on 7.5 volts. This resistance is

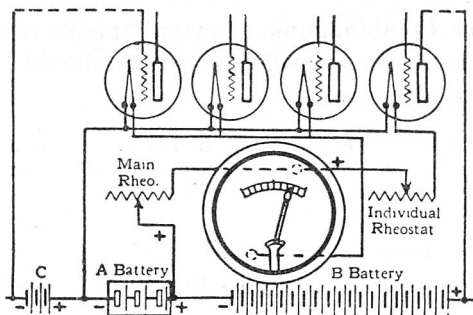


FIG. 7,382.—Ammeter connections for a radio set with four dry cell tubes. Having the individually adjusted filament in series with the main rheostat, but not in the ammeter circuit, prevents it ever having more than normal current.

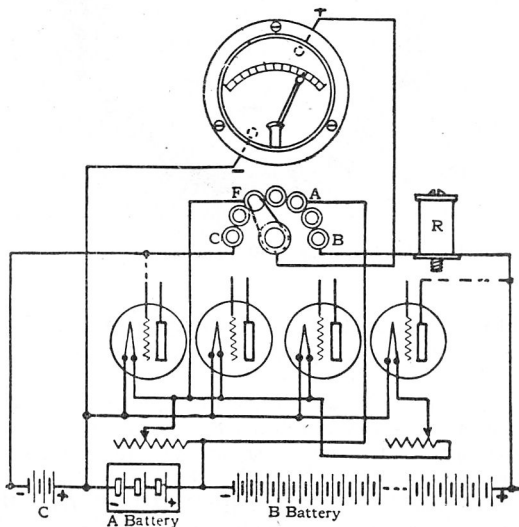


FIG. 7,383.—Dial switch control for multi-range volt meter; C, C battery volts to left; F, filament volts, lower right; A, A battery volts, lower right; B, B battery volts, upper right.

supplied on a spool external to the volt meter proper so that it may be inserted in the circuit between the high voltage and the contact button on the switch for that voltage. With a seven contact switch, four values may be read from this one volt meter, including A battery volts.

In all cases the minus (common) of the volt meter should be connected to the minus bus bar of the filaments, as shown in fig. 7,383, then ϕ F, A, and B, will be plus, causing deflection of the volt meter pointer to the right, and C, will be minus, causing deflection to the left of zero. The switch should never be left on B, or C, except while taking readings.

Several switching schemes have been worked out for the control of the volt meter for uses such as with radio sets.

Fig. 7,384, shows how a standard radio jack may be used with a metal plug and a double range volt meter to control the *on* and *off* of the set

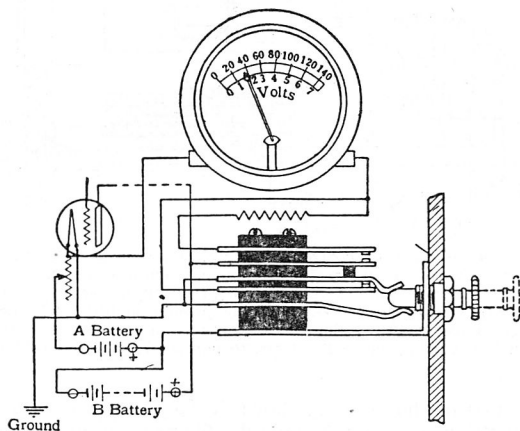


FIG. 7,384.—Volt meter and tube control with a standard jack. 1, plug removed, rheostat off = set off, A battery ready to charge; 2, plug in normal, rheostat on = set operating, volt meter showing filament voltage; 3, plug pressed entirely in, rheostat on or off = volt meter indicates B battery voltage; 4, plug released, returns to normal. The switch is a standard radio jack plus a metal plug whose shank is $\frac{1}{4}$ in. in diameter, approximately 1 in. long and has a hemispherical end. The main frame of the jack is connected to +A and -B. The two prongs which usually receive the plug are connected together and to the plus bar of all filaments, +F. The common of the volt meter is connected to the minus bus bar of the main filaments. The ground G, may be connected either to +A, or to +F. The contact between the main prongs is connected to the plus terminal of the low range of the volt meter. The two upper contacts are connected in the high voltage; B, circuit with the multiplier resistance somewhere between +B. and the plus of the low range of the volt meter.

as well as the indication of filament volts and B battery volts. This arrangement is ideal for radio sets having dry cells for A battery. The common of the volt meter is connected to the minus bus bar of the main filaments.

If one vacuum tube be used with an individual filament rheostat, the extra filament and rheostat should be in series with each other across the positive and negative bus bars of the main filaments. Then the voltage of the individually controlled filament would never be greater than that applied to the main lot, and this is shown by the volt meter.

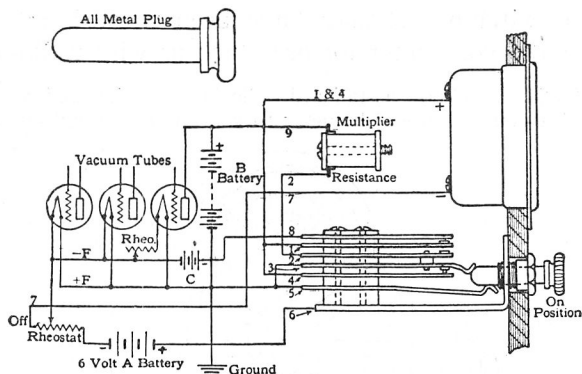


FIG. 7,385 and 7,386.—Volt meter control switch and lock with special jack. 1, plug removed, rheostat off = set locked off, A battery ready to charge; 2, plug inserted, rheostat off = volt meter indicates storage battery voltage; 3, plug inserted, rheostat on = set in operation, volt meter indicates filament voltage, lower right; 4, plug pressed slightly, volt meter indicates B battery voltage, upper right; 5, plug pressed entirely in = volt meter indicates C battery voltage, lower left; 6, plug released, returns to normal; 7, plug removed, = set locked off.

In operation of the hook up shown in fig. 7,384 when the metal plug is inserted in the jack, the vacuum tube filaments immediately light up, if the rheostat is on, and the volt meter shows the voltage applied to the filaments. The filament rheostat is advanced as the dry cells age, so as to keep proper voltage on filaments. When the metal plug is pressed in so as to lift one prong and break the circuit between the volt meter and the plus of the filament, the pointer returns to the zero of the scale. As the pressure on the head of the plug is increased, the upper contacts close and the volt meter indicates B, battery voltage. When the operator's finger is withdrawn, the plug returns to its natural position with instrument indicating filament volts. The jack will not remain in the B battery

position. Thus all danger of accidentally exhausting the B battery is avoided. When the plug is removed, the filament circuit is open and hence all flow of current stopped.

If the A, battery be of the storage cell type, the rheostat may be turned off when the plug is removed, so that both sides of the storage battery are disconnected from the set.

In this case $-B$ should be connected to G and to $+F$, and not to $+A$. With such an arrangement, the storage battery may be charged with a rectifier, even though this rectifier does not have a transformer with an insulated secondary winding.

An ideal arrangement for multi-tube sets having storage A batteries is shown in figs. 7,385 and 7,386.

This scheme gives every combination of circuits and every combination of volt meter readings that can be desired. This switch is similar to that shown in fig. 7,384, with an additional top contact for C battery indication. The contact below this goes to the plus of the low range of the triple scale volt meter. The contact below this one goes through the multiplier resistance to $+B$. Also $+F$, $-B$, and G , are together. The plus of the C battery goes to $-A$, or to $-F$. In this case the minus common of the high resistance volt meter goes to the *off* end of the main or low resistance rheostat.

When the rheostat is off this is equivalent to $-A$, but when rheostat is on this is equivalent to $-F$, since the drop in the rheostat due to the small current of the volt meter is negligible, but the drop in the rheostat due to the filament current is not negligible. The functioning of this switch is much the same as for fig. 7,384, except that the C battery circuit is added. As the plug is pressed in it first disconnects the positive terminal of the volt meter from the filament circuit, then connects it through the multiplier resistance to the B, battery circuit. Then with further pressure, the plug forces the upper contacts together and the minus of the C, battery is connected to the normally plus terminal of the volt meter. This causes the volt meter pointer to deflect to the left of zero on the C, scale. Meanwhile the multiplier resistance current from $+B$, is shunted through the low resistance of the C battery, and thence to $-B$, without passing through the volt meter. Thus it is seen that the volt meter indicates C battery voltage without any appreciable error due to the current through the multiplier.

The triple scale volt meters: 5-0-7.5 and 0-150; also 6.5-0-10 and 0-100 volts, are ideal for the switching arrangement just mentioned.

With this arrangement, every operation is logical. No harm can be done the volt meter or the batteries. The scale readings cannot be mistaken, for normal position of plug is always filament volts if set be operating; pressure with deflection to right is always B, volts; greater pressure and deflection to left is always C, volts; release always results in return to normal.

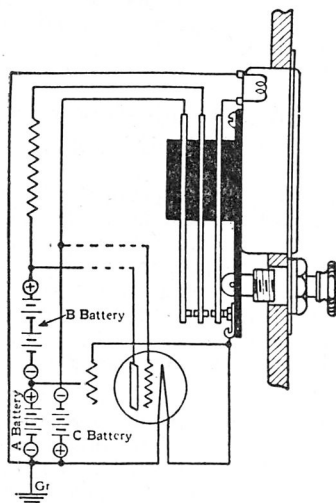


FIG. 7,387.—Push switch scheme, with special contactors mounted on back of volt meter, for indicating filament, B battery and C battery volts. The contacts do not act as a battery switch but merely control the volt meter. To give best results, the *common* of the volt meter is connected to the minus of the filaments. This is preferably the plus of the C battery and the minus of the A battery. The minus of the B battery may be connected to either the plus or minus of the A battery. The B reading would include that of the A battery in the first case, but not in the second. The contacts of the switch shown may be made from standard jack contacts or may be made much smaller to go on the back of a small volt meter. The contact in the insulating base passes to the positive side of the vacuum tube filaments and also through the filament rheostat to the plus of the A battery. The first spring contact, normally pressing on the stationary contact, is connected to the plus of the low range of the volt meter. The next spring contact, normally not touching contacts at either side, is connected through the volt meter multiplier resistor to the plus of the B battery. The last contact is connected directly to the minus of the C battery.

Thus one switch unit and one volt meter serve for all desired functions and do away with all guess work as to condition of A, B, or C batteries, and filament voltage. Removal of the plug protects the filaments from being harmed by children turning on the rheostat to the extreme position.

These general ideas may be modified in many ways. The standard jack construction may be followed only in part. The shank of the plug may have a pin in it passing through a slot in the switch head, so that the plug may be twisted after insertion, so that it will not slip out and accidentally break the circuit. The round metal plug may be replaced by a flat key with different side grooves or ridges, with corresponding openings in the different jack heads. Such a construction would be a lock against tampering.

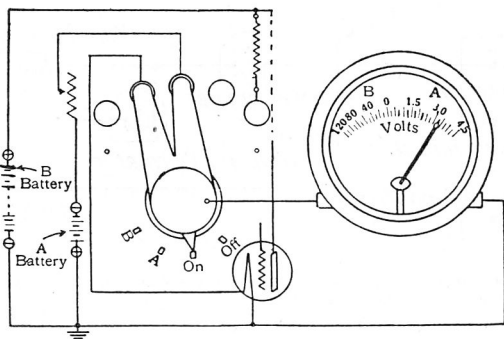


FIG. 7,388.—Filament and volt meter control with a double blade switch, with off, filament, A battery and B battery voltage positions. When the double blade switch is in the off position, one finger is in an inactive position, while the other finger is on a button contact leading to the negative side of the filaments. In the next position, on, the fingers bridge this negative filament button and a button contact leading through the filament rheostat to the negative end of the A battery. This turns on the filament current and causes the volt meter to show filament voltage on the A, scale, one side of zero. In the next position, A, the double blade is active only through the rheostat to the A battery, the filament being cut off. This position causes the volt meter to show the A battery voltage, on the same A, scale. This is necessary in order to know when the filament battery is completely charged or discharged. The drop in the rheostat due to the small volt meter current is negligible, and hence introduces no error. In the next position B, the blade touches a contact leading through the volt meter multiplier resistor to the plus of the B, battery. This setting causes the volt meter pointer to deflect in the opposite direction and show the B, battery voltage on the B, scale. The switch should not be left in the B, position for any great length of time. A spring may be provided to move the switch blade away from this last contact when the knob is released by the operator. Merely the insulated knob and a pointer may appear on the outside of the panel, with off, on, A and B, engraved thereon. This scheme has the advantage that the A and B, readings cannot be confused and that the switch controls the on and off of the vacuum tube set as well as the functioning of the volt meter.

Another push switch scheme for indicating filament, B battery and C battery volts on the triple scale double range volt meters, is shown in fig. 7,387.

In operation (fig. 7,387), the volt meter will normally show filament volts whenever the rheostat is on. A slight pressure on the button breaks the contact to the plus of the filament and makes the contact to show B battery volts. A greater pressure on the button throws the three spring contacts together and causes the low range of the volt meter to be connected across the C battery. The current through the multiplier continues to flow, not through the volt meter but through the C battery, and A battery to -B. Thus the volt meter pointer deflects to left of zero and shows

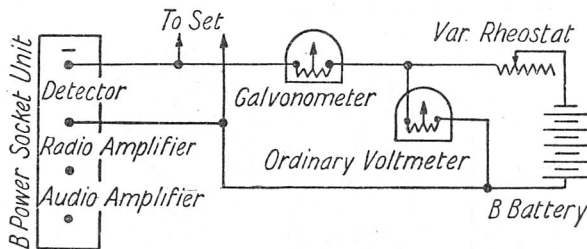


FIG. 7,389.—Potentiometer method of obtaining correct readings of B power unit voltages with galvanometer and ordinary volt meter.

C battery volts on the C, scale. When the button is released the springs return to normal and the volt meter to filament volts. The vacuum tube set is turned on or off by the rheostat.

A switching arrangement which can be made up of standard parts is shown in fig. 7,388.

Milli-Ammeters.—These instruments are provided with fine wire coils of many turns. Those marked in milli-amperes range from 0-10 to 0-100, and are for use in plate circuits of vacuum tubes, and for other purposes where a few volts drop is not harmful.

The 0-10 milli-ammeter may have its terminals connected to a standard plug and thence inserted into any jack intended for head phones or loud

speaker, so as to measure the vacuum tube plate current in that circuit. The voltage drop in the milli-ammeter is much less than that in any head phone or loud speaker, and hence this drop is no detriment for such uses.

A combination instrument is made with a scale of from 0-10 milli-amperes at from 0-25 volts with arrows at 17.5 and 22.5 volts, representing empty and full B battery block.

With an external multiplier, this same instrument reads from 0-100 volts so as to show total voltage of four or less blocks of B batteries in a set. This instrument may be used to advantage on a B, battery eliminator, placing the 100 volt range clear across the main condenser, and tapping off, where the multiplier joins the low range resistor, to feed the detector at approximately one quarter total voltage. In such a case the volt meter readings will be correct only when the detector plate current is small compared with 10 milli-amperes. A bridging condenser should be used to keep this lowered voltage constant while the set is operating. Thus this one instrument serves not only as a milli-ammeter and as a double range volt meter, but also as a 10,000 ohm potentiometer with tap at 2,500 ohms for voltage reduction.

Double Range Ammeters.—These instruments are particularly good for double duty rectifiers.

The minus common of the ammeter is connected to the minus (anode) of the rectifier. Two other terminals are supplied, one for 0-5 amperes for A battery charging, and the other for 0-1 ampere for B battery charging.

The usual number of plus terminals for 2, 6, 12, 22.5, 45, and 90 volt batteries should be supplied on the rectifier as usual. Other double ranges are supplied such as: 0-1.5 and 0-7.5, also 0-2 and 0-10 amperes.

TEST QUESTIONS

1. *What is the requirement of a volt meter for radio instruments?*
2. *Why is it necessary that a volt meter draw a very small current?*
3. *Why are inefficient ammeters especially undesirable?*

4. *Name an efficient type of ammeter.*
5. *What is the advantage of a combination instrument?*
6. *Name some volt meter combinations.*
7. *What kind of a switching device should be used?*
8. *How should a switch be selected?*
9. *Draw a diagram for radio connections with four dry cell tubes.*
10. *Draw a diagram showing dial switch and control for multi-range volt meter.*
11. *Describe the method of volt meter and tube control with a standard jack.*
12. *Why is a volt meter control switch and lock arranged with special jack?*
13. *Describe an ideal arrangement for multi-tube sets.*
14. *What are the advantages of triple scale volt meters?*
15. *Draw a diagram showing filament and volt meter control with a double blade switch.*
16. *How are milli-ammeters constructed?*
17. *What is the range of a milli-ammeter scale?*
18. *On what circuits is a milli-ammeter used?*
19. *How is a 0-10 milli-ammeter connected?*
20. *How does the voltage drop in a milli-ammeter compare with that in a head phone or loud speaker?*
21. *Explain the use of a bridging condenser.*
22. *What is the advantage of a double range ammeter?*
23. *How is a double range ammeter connected?*

CHAPTER 182

Broadcasting Stations

(Transmitting Apparatus)

The essential elements of a transmitting station consist of:

1. Source of energy.

Such as a storage battery, *d.c.* or *a.c.* supply, steam engine, or any other source from which energy might be obtained.

2. Oscillator, or high frequency alternator.

The device for converting the available energy into the form of high frequency currents.

3. Controlling device.

Such as key, which makes and breaks a circuit, or modulator which varies the amplitudes of the high frequency current in accordance with sound waves which it is desired to send out.

4. Antenna.

The device for radiating the energy due to the high frequency current into space in the form of electro-magnetic waves.

The Vacuum Tube as an Oscillator.—A vacuum tube may be used as a generator of high frequency voltages, and when so used it is called an *oscillator*. When the vacuum tube is

used as an oscillator the A, B and C batteries form the source of energy and the tube is connected to the oscillatory circuit, so that there is coupling between the grid circuit and the oscillatory circuit and also between the plate circuit and the oscillatory circuit, as illustrated in fig. 7,390.

From the explanation of the diagram, it is seen that by associating the battery source of energy and the oscillatory circuit with the vacuum tube in such a way as to provide suitable coupling between the plate circuit and the oscillatory circuit, and between the grid circuit and the oscillatory

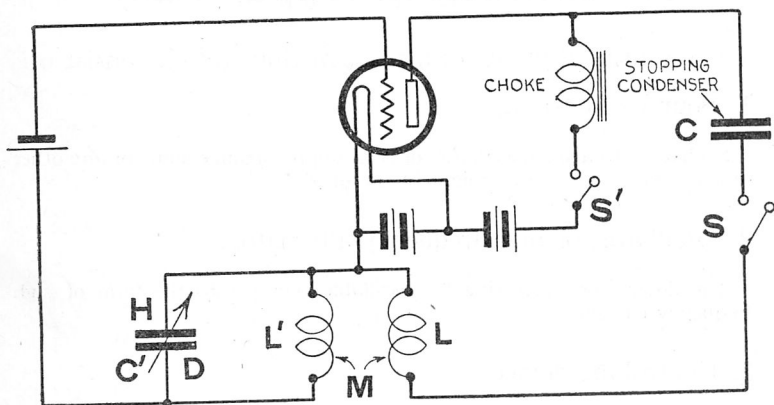


FIG. 7,390.—Modified Hartley type oscillator. *In operation* with switch S open and S', closed, the B battery sends a steady current through the choke coil and the internal plate circuit. Condenser C, prevents this *d.c.* flowing through coil L, when S is closed, thus preventing discharge of B battery through coil L, and also making the reactance of the circuit LC, to *r.f.* currents low. When S, is closed a surge in current takes place via condenser C and coil L, which is absorbed from the internal plate circuit. Since the choke maintains the battery current steady, the variable current through coil L induces a voltage in coil L'. Assuming the induced voltage is such as to cause a surge of current down through coil L', the condenser C' would be charged with the plate D positive. The voltage across this condenser would then be in opposition to the original grid bias, and would, consequently make the grid less negative than before. This decrease in negative grid voltage would effect an increase in the internal plate current. Because of the choke coil in the battery circuit the increased current must flow down through the coil L, and up through the condenser C, which in turn would induce a voltage in the coil L', causing a surge of current up through this coil and charging the condenser C' with the plate H, positive. Now, the voltage across the condenser C', aids the original grid bias and results in an increased negative grid voltage and therefore the current from plate to filament is decreased again, with the resulting surge of current down through C, and up through L, which induces a voltage in L', and so the cycle is repeated indefinitely.

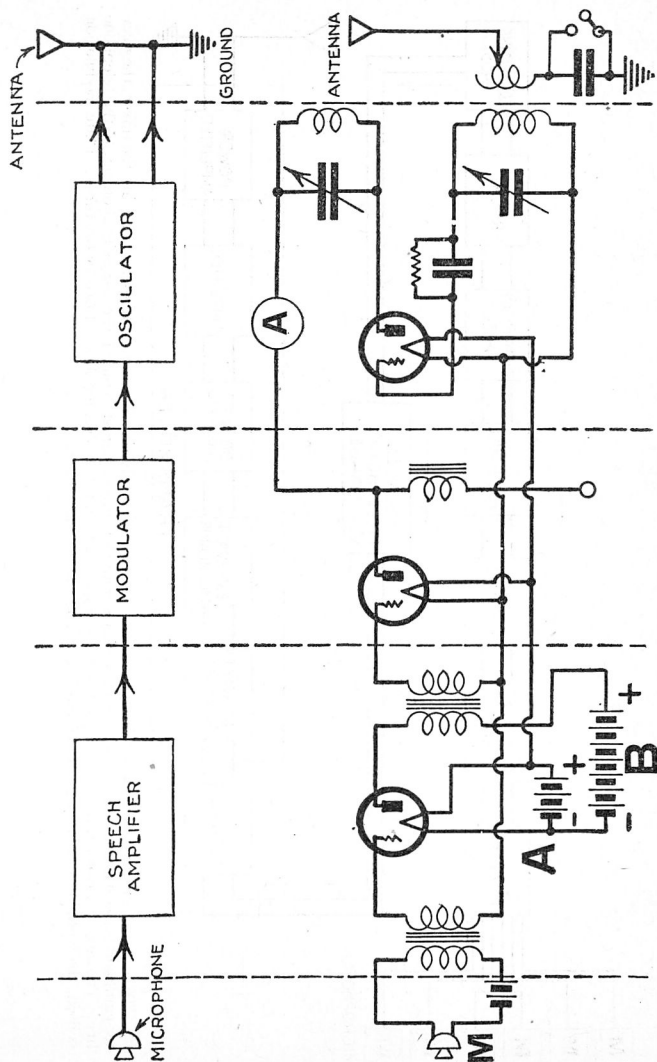


Fig. 7,391.—Arrangement of elements of radio transmitting station.

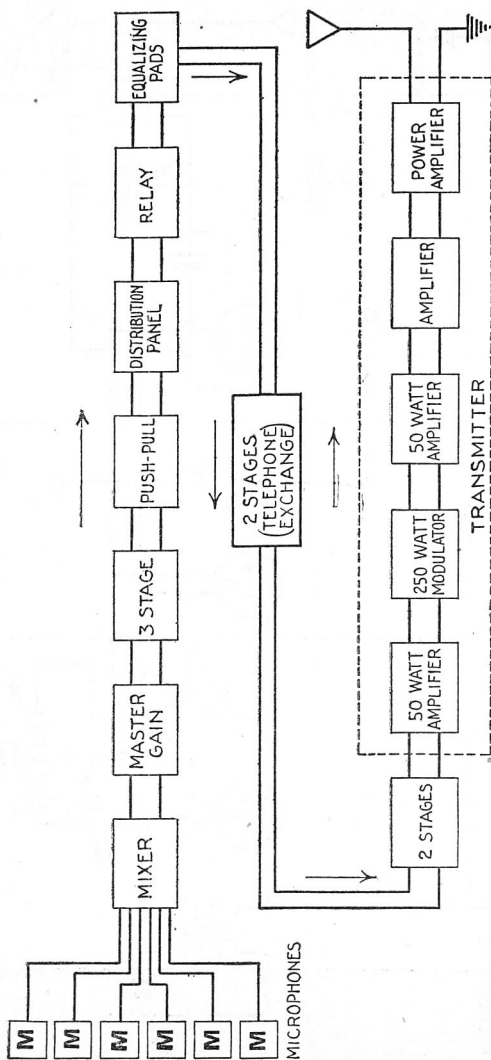


FIG. 7,392.—Arrangement of elements of Hollywood broadcasting station KNX. The most interesting units are the mixer, the master gain, and the equalizing pads; the latter are merely circuit elements designed to match the relay signal output to the telephone line. The amplifier consists of three stages, using 250 watt tubes, and the power amplifier of two 10 kw. tubes. Plate modulation is used, the modulator being capacity coupled to the 50 watt $r.f.$ amplifier.

circuit, there is produced sustained oscillations, thus some of the available battery energy is converted into the form of high frequency currents.

Because of the amplifying action of the vacuum tube, the alternating voltage across the grid condenser C' , during a given cycle would result in an increased alternating voltage across the coil L , in the plate circuit, and consequently with sufficiently close coupling between L and L' , the voltage induced in coil L' would be greater than that which previously existed across the condenser C' . For this reason the amplitude of each cycle would be greater than that of the preceding cycle, and the oscillations of the plate current would continue to increase until the instantaneous values of plate current varied between some maximum and some minimum determined by the coupling and the constants of the circuit. The form of this oscillating plate current is shown in fig. 7,394.

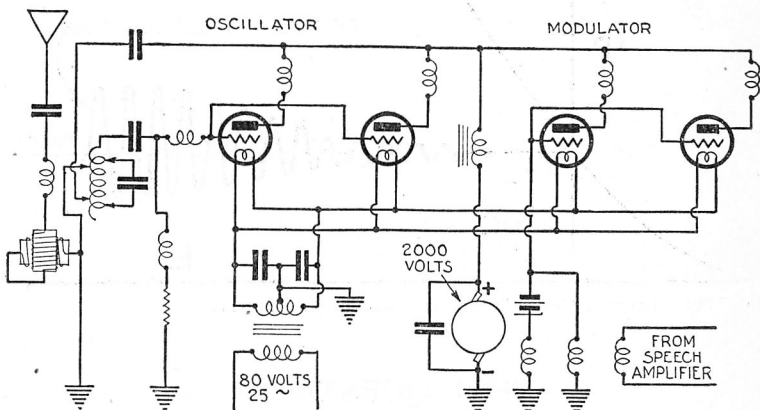


FIG. 7,393—Circuit diagram of a broadcasting station.

Broadcasting Station Circuits.—One example of a transmitting circuit is shown in fig. 7,393. The oscillator used in this circuit contains two tubes in parallel and is of the Meisner type. The modulator also employs two tubes in parallel, and modulation is effected by means of variation of the input power (Heising system).

The general arrangement of the various units comprising the apparatus of a large transmitting station is clearly shown in the circuit sequence diagram of Hollywood Station KNX, as shown in fig. 7,392.

By means of the master gain controls the sound level is kept down within reasonable limits. The speech currents are mixed, amplified twice, and then sent through the equalizing pads, over the telephone wires, amplified again in the telephone exchange, and yet again at the station before entering the modulator. The monitoring is done here, and the needle of the meter is not allowed to swing past the red mark on either side of zero. All equipment is, of course, in duplicate as an emergency measure.

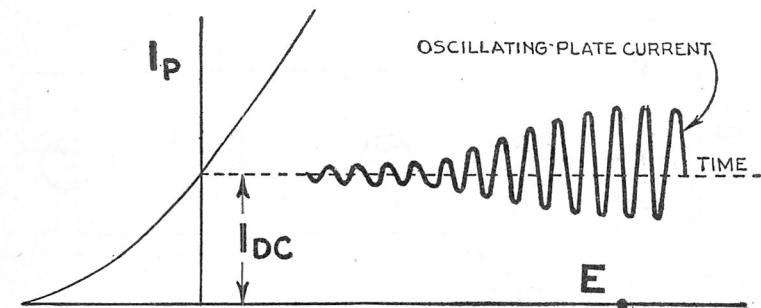


FIG. 7,394.—Diagram showing form of the oscillating plate current.

TEST QUESTIONS

1. What other name is given to a broadcasting station?
2. Name the essential elements of a transmitting station.
3. Is an aerial or an antenna used at a broadcasting station?
4. Describe an oscillator.
5. Draw a diagram showing the various circuits of a broadcasting station.

CHAPTER 183

Radio Troubles

The service man, in order to intelligently cope with the various faults liable to develop in radio sets should be provided with a compact portable *testing set* of which there are a number of good ones available.

The author has selected for illustration in this chapter a test set known as a *Diagnometer*, Model 400 B, made by the Supreme Instrument Corp. It comprises equipment for testing as follows:

- | | |
|------------------------|---------------------------|
| 1. Tube tester | 5. Analyzer |
| 2. Modulated radiator | 6. Continuity tester |
| 3. Resonance indicator | 7. Rejuvenator |
| 4. Neutralizer | 8. External use of meters |

The first step in servicing should be a preliminary inspection of the operating characteristics of the radio, and as this can best be done by actually tuning the radio to signals, if the radio be not completely inoperative, it is advisable to put the *modulated radiator* in operation. After a preliminary examination of the radio, the next step should be the testing of the tubes used in the radio, which is also accomplished with the *modulated radiator* circuits, preferably powered through the *power plant*.

Putting the Power Plant in Operation.—Where alternating current power, of the voltage and frequency for which the testing set is designed, is available, the following procedure puts the *power plant* in operation for powering the *modulated*

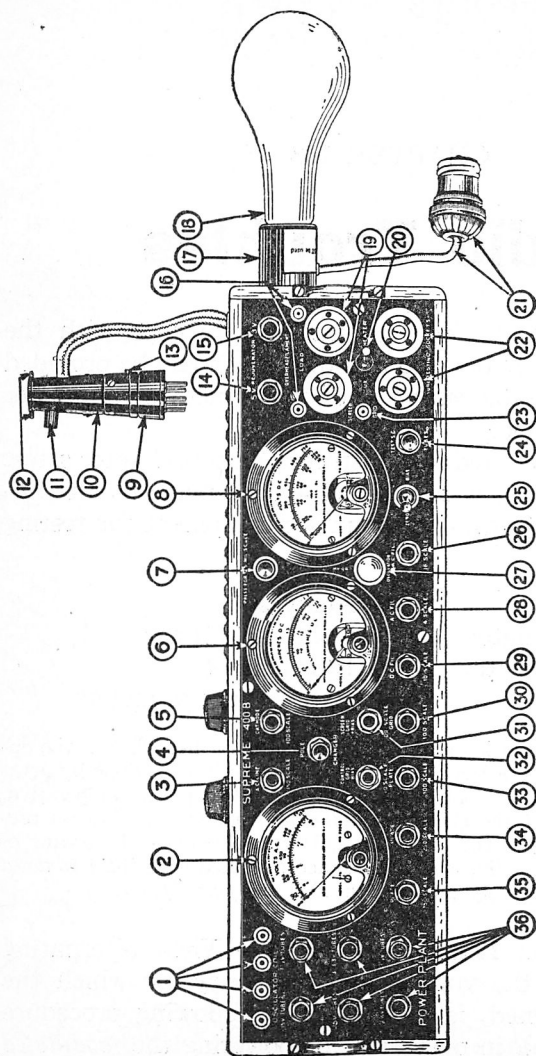


FIG. 7,395.—Supreme *diagnometer* showing front panel markings. *The markings are:*

1. Oscillator coil pin jacks marked B.P.G.F.;
2. A.c. volt meter, 4 scales 750/150/16/4/0;
3. A.c. line jack, for connecting 150 volt scale of a.c. supply line 21;
4. Pole changer push button switch for reversing connections to the d.c. volt meter 8, when the needle backs off scale during d.c. filament 29, or cathode 5, analysis;
5. Cathode bias jack, for indicating cathode biases on the 100 volt scale of the d.c. volt meter 8, when analyzing from UY sockets with the UX heater switch 20, in the heater position;
6. D.c. milli ammeter, the 125 mil. scale of which is in the common plate circuit of the 4 sockets 19 and 22. The 2½ ampere scale is available externally only;

FIG. 7,395.—*Text continued.*

7. Milli ammeter switch for opening a shunt for the 25 milli ampere scale range 6;
8. *D.c.* volt meter, 4 scales, 750/250/100/10/0;
9. Analyzer adapter for UY sockets;
10. Universal analyzer plug. This plug should be removed from any radio tube socket before connecting the *diagnometer* to the *a.c.* supply line 21;
11. Control grid contact lug on the analyzer plug 10;
12. Top heater tube filament contacts on the analyzer plug 10;
13. Adapter release on the analyzer plug 10;
14. Jack for rejuvenating 5 volt tubes of thoriated filament types;
15. Jack for rejuvenating 3 volt tubes of thoriated filament types;
16. Overhead (top) heater tube filament pin jacks;
17. Polarized series socket adapter for 100 watt Mazda protective lamp;
18. 100-watt Mazda lamp;
19. Load sockets used when analyzing from radio tube sockets;
20. UX heater switch. To be left in *heater* position when analyzing from radio sockets which utilize tubes having independent cathodes. For all other tube socket analysis, leave the switch in the UX position;
21. *A.c.* power supply cord and plug. To be detached when analyzer plug 10, is to be inserted in any radio tube socket;
22. *Tube testing sockets* used when the testing set employs any tube while connected to an *a.c.* power supply system;
23. Screen grid jack for connecting to the control grid contact on top of any screen grid tube placed in any of the testing set tube sockets;
24. Switch to be depressed when testing screen grid tubes and the second plate of full wave rectifying tubes placed in either *tube testing socket* 22;
25. Switch for applying either of two grid voltages to the grid of any tube placed in a tube testing socket 22;
26. *A.c.* filament jack for connecting 16 volt scale of *a.c.* volt meter 2, across the filament contacts of the analyzer plug 10;
27. Push button switch for shunting G and F of the oscillator coil pin jacks 1, to *stop oscillation* of any amplifier tube used in a *tube testing socket* 22;
28. *A.c.* filament jack for connecting the 4 volt scale of the *a.c.* volt meter 2, across the filament contacts of the analyzer plug 10;
29. *D.c.* filament jack for connecting the 10 volt scale of the *d.c.* volt meter 8, across the filament contacts of the analyzer plug 10;
30. Grid jack for connecting the 100 volt scale of the *d.c.* volt meter 8, across the grid and cathode contacts of the analyzer plug 10, for indicating negative grid bias;
31. Screen grid jack for connecting the 100 scale of the *d.c.* volt meter 8, across the grid and cathode contacts of the analyzer plug for indicating positive screen grid bias;
32. Control grid jack for connecting the 10 volt scale of the *d.c.* volt meter 8, across the control grid contact lug 11, and the cathode contact of the analyzer plug 10, for indicating negative control grid bias;
33. Plate jack for connecting the 100 volt scale of the *d.c.* volt meter 8, across the plate and cathode contacts of the analyzer plug 10 for indicating positive plate voltages below 100 volts;
34. Plate jack for connecting the 250 volt scale of the *d.c.* volt meter 8, across the plate and cathode contacts of the analyzer plug 10, for indicating positive plate voltages between 100 and 250 volts;

radiator for a test of the tuning characteristics of a radio, for the testing of tubes, and for other purposes:

1. Remove the oscillator coil from its pin jack position.
2. Open all switches on the panel of the testing set.
3. Clear the analyzing plug and all jacks of the testing set from contact with any electrical conductors which might short circuit any of the jack

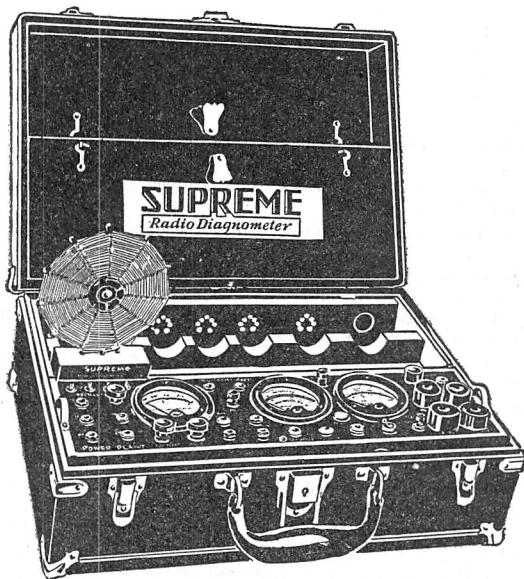


FIG. 7,396.—Supreme radio diagnometer in carrying case which provides adequate space for all tools that may be required as well as spare tubes and parts. Illustration shows oscillator coil in position and swinging tube shelf that provides accessibility and protection to tubes. Instrument can be used in carrying case or removed, as desired.

FIG. 7,395.—Text continued.

35. Plate jack for connecting the 750 volt scale of the *d.c.* volt meter 8, across the plate and cathode contacts of the analyzer plug 10, for indicating positive plate voltages between 250 and 750 volts;
36. Power plant jacks for applying a filament voltage which corresponds to the filament rating of any tube placed in either of the *tube testing sockets* 22, when the testing set is connected with the supply cord 21, to an *a.c.* supply system.

switches, or which might be grounded or directly connected to the common alternating current system. This will avoid the possibility of shunting power supply around the protective resistor.

4. Remove the prescribed protective resistor from its series socket of the *a.c.* connector cord.

5. Connect the testing set to a convenient *a.c.* supply socket, using the *a.c.* connector cord with its series socket vacant.

6. Close the *a.c.* line switch. If the *a.c.* volt meter show any reading, the series socket is shorted, and the deficiency must be corrected before proceeding with any test.

7. If the *a.c.* volt meter show no reading, replace the protective resistor in its series socket of the *a.c.* supply connector cord. The *a.c.* line voltage should then be indicated on the *a.c.* volt meter. This switch may remain closed so that line voltage fluctuations may be observed. A shorted tube, or other short circuit within the circuits supplied with the *power plant* will be indicated by a radical drop of the volt meter reading.

Putting the Modulated Radiator in Operation.—With the *power plant* in operation, the following steps complete the set up of the *modulated radiator* for a check up of the pick up characteristics of a radio, for tube testing, and for other purposes:

1. Insert the oscillator coil, with its label to the front, in its prescribed position.

2. Throw the UX heater switch to its heater position.

3. Place a good oscillating tube in one of the tube testing sockets. Use a clip pin plug lead for connecting the top control grid contact to the screen grid pin jack on the instrument panel.

4. Throw the biasing toggle switch to the position for maximum oscillation.

5. Leave the ammeter milli-ammeter scale switch in position for readings on the highest available scale of the meter.

6. Close the *power plant* switch, the voltage marking of which corresponds to the filament specification of the tube which has been placed in one of the tube testing sockets.

7. When using screen grid tubes, close the test S. G. tubes switch momentarily for obtaining plate readings of the tube.

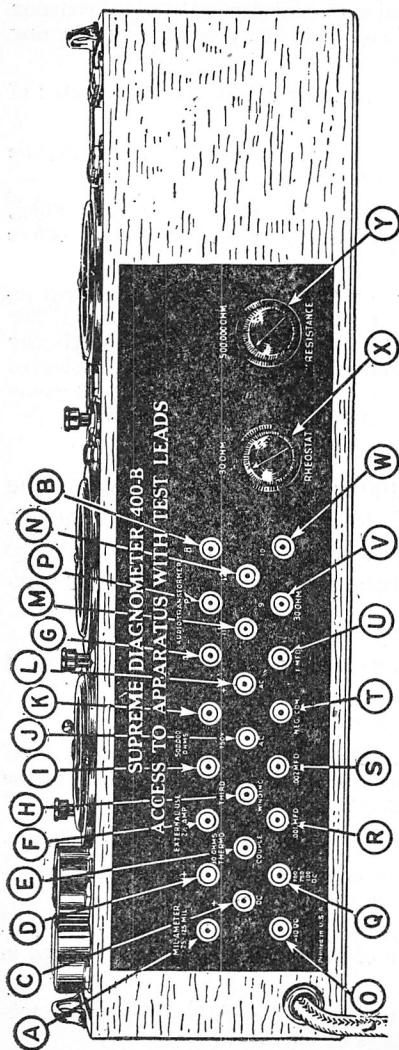


FIG. 7,397—Supreme diagonometer showing rear panel markings for external connections.

The markings of the diagonometer (fig. 7,397) are:

- A. Connects to negative side of 125 mil. scale of *d.c.* milli-ammeter 6. Positive side connects to D. 25 mil. scale available by depressing milli-ammeter switch 7.
- B. Connects to one side of primary circuit of audio transformer. Other side of primary connects to P;
- C. Common positive connection for all scales of *d.c.* volt meter 8. Negative connections available at O and Q when a corresponding jack 29, 33, 34 or 35 is closed;
- D. Common positive connection to *d.c.* milli-ammeter 6. Negative 125 scale available at A, without closing any switch or jack. Negative 25 mil. connection completed at A, by depressing milli-ammeter switch 7. Negative connection to 2½ ampere scale of *d.c.* milli-ammeter 6, completed at F, without closing any switch or jack.
- E. One side of 30 ohm rheostat X, and thermo couple heater unit of *d.c.* volt meter 8. Other side of 30 ohm rheostat available at F. Rheostat should not be used as a filament control with a battery hook up of the testing set;
- F. Negative connection to 2½ ampere scale of *d.c.* ammeter 6. Positive connection completed at D, without closing any switch or jack;
- G. One side of secondary winding of audio transformer which is completed at T;
- H. One side of third (low impedance secondary) winding of audio transformer. The other side is completed at E;

8. The plate current, which includes whatever additional current which may be induced by the oscillatory circuit, will then be indicated on the milli-ammeter.

9. If the current reading do not exceed the next lower scale limit, the milli-ammeter scale switch should be closed to the position for readings on the next lower scale. Observe the value of the current.

10. Close the oscillation switch and observe the plate current reading with the tube not in an oscillating condition. The audible strength of the radiated signal will generally be in proportion to the difference in the current readings obtained.

Operating Modulated Radiator with Batteries.—Where alternating current power supply of the voltage and frequency for which the testing set is designed is not available, the oscillatory

FIG. 7,397.—*Text continued.*

- I. One side of 500,000 ohm variable resistor Y. The other side is completed at K, the resistor being independent of all other circuits;
- J. One side of 750 volt scale range of *a.c.* volt meter 2. The other side is completed at L, without closing any panel switch or jack;
- K. One side of 500,000 ohm variable resistor. The other side is available at I;
- L. Common connection for all scales of *a.c.* volt meter 2. The other side of the 4 and 16 volt scale ranges is available at U, when a corresponding panel jack 28, or 26, is closed. The other side of the 150 volt scale range is available at D, when the *a.c.* line panel jack 3, is closed. The other side of the 750 volt scale range is available at J, without closing any panel switch or jack;
- M. One side of thermo couple heater unit. The other side is available at E;
- N. To be connected to C, for closing thermo couple heater unit to 1 mil. movement of *d.c.* volt meter 8;
- O. Connects to negative side of 10-scale of *d.c.* volt meter when panel jack 29, is closed for completing the positive meter connection to C;
- P. One side of audio transformer primary. The other side terminates at B;
- Q. Connects to negative side of 100, 250 and 750 volt scale ranges of *d.c.* volt meter 8, when a corresponding panel jack 33, 34 or 35, is closed for completing the positive meter connection to C;
- R. One side of 0.001 mfd. fixed condenser. The other side connects to T;
- S. One side of 0.002 mfd. fixed condenser. The other side connects to T;
- T. Common connection of each condenser terminating at R, S, and U; also connects to filament end of audio transformer secondary;
- U. One side of 1 mfd. fixed condenser. The other side connects to T;
- V. One side of 30 ohm rheostat X. The other side connects to E;
- W. Connects directly to V;
- X. Control knob of 30 ohm rheostat available at E and V;
- Y. Control knob of 500,000 ohm variable resistor available at I and K.

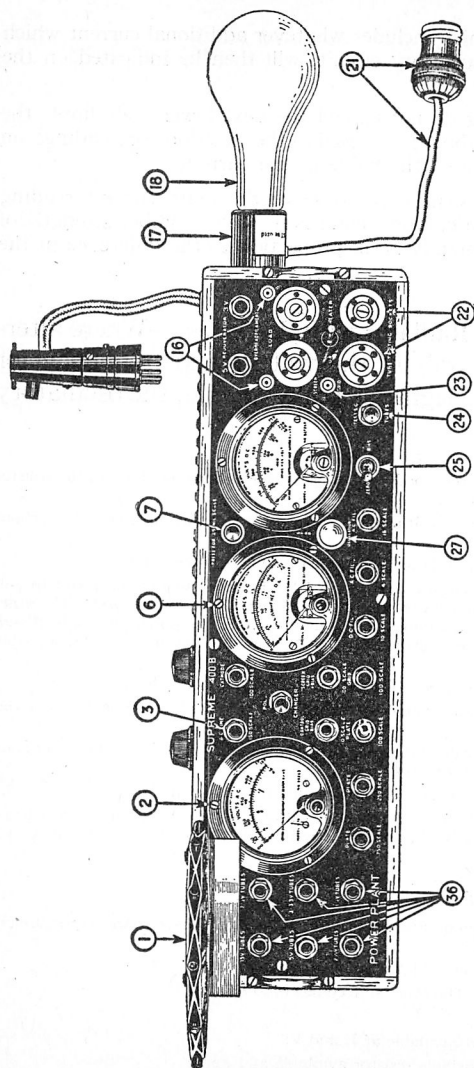


FIG. 7,398.—Supreme oscillator operation modulated with a.c. supply.

- A. Remove any jumpers or test leads which may have been left connected to the instrument, open all jack switches on the panel, and clear the analyzer plug 10, from contact with any electrical conductors which may be grounded or connected to the common a.c. supply system.
- B. Insert the polarized series socket adapter 17, without the 100 watt Mazda lamp 18, in the receptacle on the end of the tray;
- C. Connect the supply plug 21, to a convenient a.c. supply outlet;
- D. Close the a.c. line jack 3. If the a.c. volt meter 2, show a reading, the series socket adapter 17, is shunted and the deficiency must be corrected before proceeding with any test;
- E. If the a.c. volt meter 2, show no reading, place the 100 watt Mazda lamp 18, in the series socket adapter 17. The a.c. supply voltage should then be indicated on the a.c. volt meter 2. No device other than the prescribed 100 watt lamp 18, should be used in the series socket adapter 17. A lower resistance would endanger the milli-ammeter;
- F. Insert the oscillator coil with its label to the front, in the prescribed position 1;
- G. Place an amplifier tube of any type, except a screen grid or top heater, on one of the tube testing sockets 22;

circuits of the *modulated radiator* may be powered with batteries, the hook up procedure being as follows:

1. Connect the common positive (*d.c.*) external pin jack of the testing set to the positive terminal of a battery the voltage of which is regulated to meet the filament voltage specification of the tube to be placed in either of the tube testing sockets.
2. Connect the -10 *d.c.* external pin jack to the negative terminal of the filament supply battery.
3. Connect the external milli-ammeter positive pin jack to the positive terminal of a 45 volt B battery.
4. Join the negative terminal of the 45 volt B battery to the positive terminal of the filament battery.
5. Close the *d.c.* Fil. switch of the testing set for observing the filament voltage.
6. Insert the oscillator coil in its prescribed position.
7. Place a tube in one of the tube testing sockets.

Using the Modulated Radiator for Tube Testing.—Tube testing is probably the most important phase of radio servicing, and every test or analysis of any radio should be preceded by a test of the tubes used in the radio with whatever replacements and rearrangements of the tubes may be required for the best

FIG. 7,398.—Text continued.

- H. Remove the jack plunger from the *a.c.* line jack 3, and insert it in the power plant jack 36, the voltage marking of which corresponds to the filament rating of the tube which has been placed in the tube testing socket 22;
- I. If the tube be generating oscillations, modulated *r.f.* signals should now be radiated at about five different frequencies within the broadcast band. These signals may be *tuned in* with any operative radio for synchronizing, neutralizing, or other purposes;
- J. The harmonic frequencies may be changed somewhat by changing the position of the *zero bias* toggle switch 25;
- K. If it be desired to increase the pickup strength of the signals, the oscillator coil intermediate winding, which terminates at two pin jacks on the back of the coil, may be coupled with test leads to the pickup circuits of a radio under test;
- L. If the oscillator signals be too strong and broad, their strength may be reduced and the tuning *sharpened* by changing the position of the jack plunger to a power plant jack of a voltage marking lower than the filament rating of the tube.

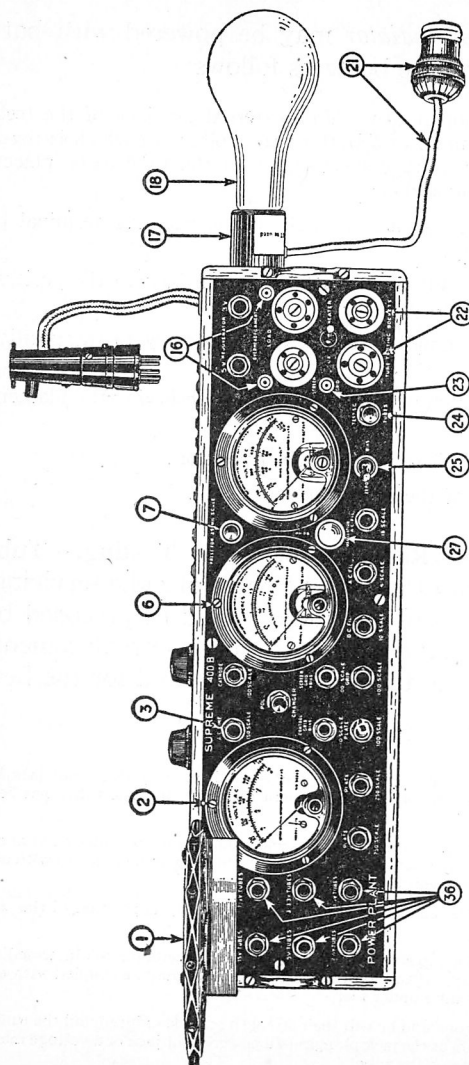


FIG. 7,399.—Supreme tube testing with *a.c.* supply. **PART 1.**—Except screen grid, rectifier, and top heater tubes.

A. Remove any jumpers or test leads which may have been left connected to the instrument, open all jack switches on the panel, and clear the analyzer plug 10, from contact with any electrical conductor which may be grounded or connected to the common *a.c.* supply system;

B. Insert the polarized series socket adapter 17, with a 100 watt Mazda lamp 18, in the receptacle on the end of the instrument tray. If any device other than a 100 watt Mazda lamp 18, should ever be used in the series socket adapter 17, the milli-ammeter 6, might be harmed or show incorrect readings;

C. Connect the supply plug 21, to a convenient *a.c.* supply outlet;

D. Close the *a.c.* line jack 3, and observe the supply voltage on the 150 scale of the *a.c.* volt meter 2;

E. Insert the oscillator coil, with its label to the front, in the pin jacks 1, marked *B.P.G.F.* on the panel;

F. The tube to be tested should be placed in one of the tube testing sockets 22.

operation of the radio. With the *modulated radiator* in operation, the following procedure is necessary to accomplish tube testing:

1. If the *radiator* be powered with alternating current, close the *a.c.* line switch and observe the line voltage reading on the *a.c.* volt meter. All tube testing tables are graduated on line voltage readings; and on the use of a 45 volt B battery where alternating current supply is not available.
2. Place the tube to be tested in one of the tube testing sockets.
3. Throw the biasing toggle switch to its zero position.
4. Leave the milli-ammeter scale switch in position for readings on the highest available scale of the milli-ammeter.
5. If utilizing *a.c.* power supply, close the *power plant* switch the voltage markings of which correspond to the filament specifications of the tube which has been placed in one of the tube testing sockets.
6. When testing screen grid tubes close the test S. G. tubes switch momentarily for obtaining the proper plate readings of the tube.
7. The plate current, which includes whatever additional current which may be induced by the oscillating circuit, will then be indicated on the milli-ammeter.
8. If the current reading do not exceed the next lower scale limit, the milli-ammeter scale switch should be closed to the position for readings on the next lower scale. Observe the value of the current.

FIG. 7,399.—Text continued.

- G. Throw the biasing toggle switch 25, to its *zero* position;
- H. Close the power plant jack 36, the voltage marking of which corresponds to the filament rating of the tube;
- I. As the tube attains its operating temperature, the plate current of the tube, as modified by the *r.f.* pulsations induced by the oscillatory circuit, will be indicated on the 125 scale of the *d.c.* milli-ammeter 6. If the plate current reading 6, is less than 25 milli-amperes, the milli-ammeter push button switch 7, may be depressed for a more discernible reading on the 25 mil. scale;
- J. Depress the *stop oscillation* button 27, for observing the plate current reading of the tube in a non-oscillating condition;
- K. With the *stop oscillation* button 27, depressed, throw the biasing toggle switch 25, to its *bias* position. The resulting change in plate current 6, is an indication of the amplifying merits of the tube under test, the greater the change for any type of tube the better the tube;
- L. Release the *stop oscillation* button 27, and observe the plate current reading 6, of the tube, as modified by the *r.f.* pulsations induced by the oscillatory circuit, with the *zero bias* toggle switch 25, in its *bias* position. A comparison of this reading on different good tubes of the same type affords an excellent means for matching tubes for the tuned stages of a radio;
- M. The four plate current readings obtained may be compared with the tube testing tables, which indicate average relationships in tube characteristics.

9. Except when testing rectifier tubes, close the oscillation switch and observe the plate current reading with the tube not in an oscillating condition.

10. Except when testing rectifier tubes the biasing switch may be thrown to its bias position, repeating the two preceding steps.

11. Compare the readings obtained with the readings shown in tube testing tables.

12. Repeat above routine for each tube to be tested.

If there be a radical difference between the values of plate current in each of the plate circuits of a full wave rectifier of



FIG. 7,400.—Supreme tube checker; portable model for either counter or portable use, with lid mounted on slip hinges, handle and detachable cord. It provides the *following features*: 1, tests pentode tubes and the new 2 volt 30 series tubes; 2, tests screen grid tubes with voltage closely approaching operating conditions; 3, full size 3½ in. meter, full bakelite case; 4, double scale meter, both scales calibrated; 5, large size transformer; 6, correct filament voltages applied to every type tube; 7, off and on switch.

NOTE.—*Screen grid tube testing with a.c. supply, fig. 7,399.*

- A. Remove any jumpers or test leads which may have been left connected to the instrument, open all jack switches on the panel, and clear the analyzer plug 10, from contact with any electrical conductors which may be grounded or connected to the common a.c. supply system;
- B. Insert the polarized series socket adapter 17, with a 100 watt Mazda lamp 18, in the receptacle on the end of the instrument tray. If any device other than a 100 watt Mazda lamp 18, should ever be used in the series socket adapter 17, the milli-ammeter 6, might be harmed or show incorrect readings;
- C. Connect the supply plug 21, to a convenient a.c. supply outlet;
- D. Close the a.c. line jack 3, and observe the supply voltage on the 150 scale of the a.c. volt meter 2;
- E. Insert the oscillator coil, with its label to the front, in the pin jacks 1, marked B.P.G.F. on the panel;
- F. The tube to be tested should be placed in one of the tube testing sockets 22, with its top control grid contact connected with a short clip pin plug lead to the screen grid 23, panel pin jack.

the filament type, the tube may not perform as efficiently as it would were both plate current values normal.

If it be desired to test both plates of full wave rectifying tubes of the filament type, depress the test S. G. tubes for obtaining a reading on the second plate.

Setting up the Rejuvenator.—Where alternating current power supply is available and it is desirable to rejuvenate tubes of the thoriated filament type, the following procedure should be followed for rejuvenating tubes in the sockets of the testing set:

1. Put the *power plant* in operation, but close no switches in the *power plant*.

2. Place a tube to be rejuvenated in the UX tube testing socket. A tube to be rejuvenated may also be placed in the UX load socket by closing the *d.c.* Fil. switch and throwing the UX to Heater switch to the UX position.

NOTE—*Continued.*

- G. Throw the biasing toggle switch 25, to its *zero* position;

- H. Close the power plant jack 36, the voltage marking of which corresponds to the filament rating of the tube;

- I. After the tube attains its operating temperature, depress the *test screen grid tubes* push button switch 24. The plate current of the tube, as modified by the *r.f.* pulsations induced by the oscillatory circuit, will then be indicated on the 125 mil. scale of the *d.c.* milli-ammeter 6.

If the plate current reading 6, in fig. 7,399, be less than 25 milli-amperes, the milli-ammeter push button switch 7, may be depressed for a more discernible reading on the 25 mil. scale.

- J. Depress the *stop oscillation* button 27, for observing the plate current reading of the tube in a non-oscillating condition;

- K. With the *stop oscillation* button 27, depressed, throw the biasing toggle switch 25, to its *bias* position. The resulting change in plate current 6, is an indication of the amplifying merits of the tube under test, the greater the change for any type of tube the better the tube;

- L. Release the *stop oscillation* button 27, and observe the plate current reading 6, of the tube, as modified by the *r.f.* pulsations induced by the oscillatory circuit, with the *zero bias* toggle switch 25, in its *bias* position. A comparison of this reading on different good tubes of the same type affords an excellent means for matching tubes for the tuned stages of a radio;

- M. The four plate current readings obtained may be compared with tube testing tables which indicate average relationships in tube characteristics.

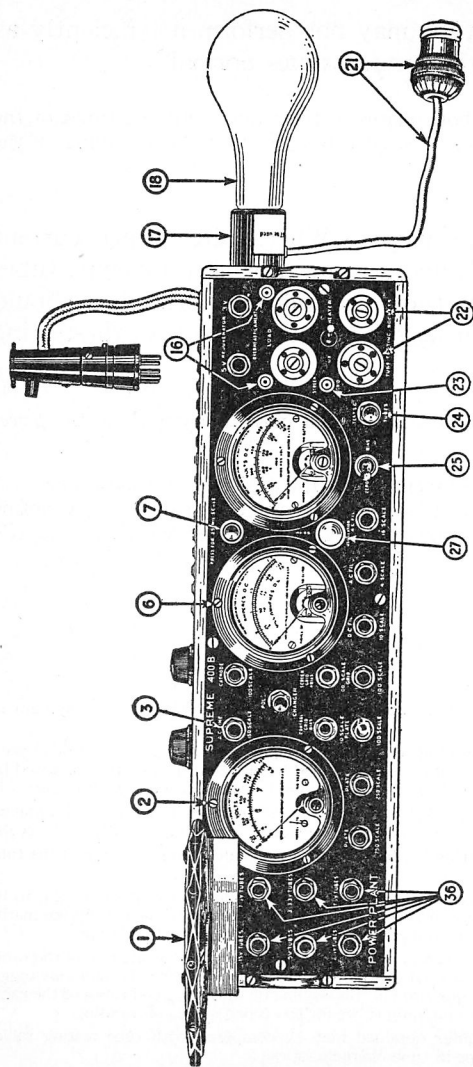


FIG. 7,401—Supreme tube testing with a.c. supply. PART 2. Rectifier (thermionic) tubes.

- A. Remove any jumpers or test leads which may have been left connected to the instrument, open all jack switches, and clear the analyzer plug 10, from contact with any electrical conductor which may be grounded or connected to the common a.c. supply system;
- B. Insert the polarized series socket adapter 17, with a 100 watt Mazda lamp 18, in the receptacle on the end of the instrument tray. If any device other than a 100 watt Mazda lamp 18, should ever be used in the series socket adapter 17, the milli-ammeter 6, might be harmed or show inaccurate readings;
- C. Connect supply plug 21, to a convenient a.c. supply outlet;
- D. Close the a.c. line jack 3, and observe the supply voltage on the 150 scale of the a.c. volt meter 2;
- E. Insert the oscillator coil, with its label to the front, in the pin jacks 1, marked B.P.G.F. on the panel;
- F. The tube to be tested should be placed in the UX tube testing socket 22;

3. Completely close the *rejuvenator* switch.
4. After 15 seconds place the *rejuvenator* switch in its semi-closed (notched) position.
5. After 10 or 15 minutes, take a test reading of the tubes which have

FIG. 7,401—Text continued.

- G. Close the power plant jack 36, the voltage marking of which corresponds to the filament rating of the tube;
- H. The current of one plate will be indicated on the 125 mil. scale of the *d.c.* milli-ammeter 6;
- I. When testing a full wave rectifier tube, depress the *test screen grid tubes* push button switch 24, for obtaining the plate current reading of the other plate;
- J. The plate current readings obtained may be compared with tube testing tables, which indicate average relationships in tube characteristics.

NOTE.—*Overhead (top) heater tubes* (fig. 7,401).

A. Remove any jumpers or test leads which may have been left connected to the instrument, open all jack switches on the panel, and clear the analyzer plug 10, from contact with any electrical conductor which may be grounded or connected to the common *a.c.* supply system;

B. Insert the polarized series socket adapter 17, with a 100 watt Mazda lamp 18 in the receptacle on the end of the instrument tray. If any device other than a 100 watt Mazda lamp 18, should ever be used in the series socket adapter 17, the milli-ammeter 6, might be harmed or show incorrect readings;

C. Connect the supply plug 21, to a convenient *a.c.* supply outlet;

D. Close the *a.c.* line jack 3, and observe the supply voltage on the 150 scale of the *a.c.* volt meter 2;

E. Insert the oscillator coil, with its label to the front, in the pin jacks 1, marked *B.P.G.F.* on the panel;

F. The tube to be tested should be placed in the UX tube testing socket 22, with its overhead (top) heater contacts connected with short clip-pin plug leads to the *overhead filament* 16, panel pin jacks;

G. Throw the biasing toggle switch 25, to its *zero* position;

H. Close the 3-3.3 V tubes power plant jack 36;

I. As the tube attains its operating temperature, the plate current of the tube, as modified by the *r.f.* pulsations induced by the oscillatory circuit, will then be indicated on the 125 mil. scale of the *d.c.* milli-ammeter 6. If the plate current reading 6, be less than 25 milli-amperes, the milli-ammeter push button switch 7, may be depressed for a more discernible reading on the 25 mil. scale 6;

J. Depress the *stop oscillation* button 27, for observing the plate current reading of the tube in a non-oscillating condition;

K. With the *stop oscillation* button 27, depressed, throw the biasing toggle switch 25, to its *bias* position. The resulting change in the plate current 6, is an indication of the amplifying merits of the tube under test, the greater the change for any type of tube the better the tube;

L. Release the *stop oscillation* button 27, and observe the plate current reading 6, of the tube, as modified by the *r.f.* pulsations induced by the oscillatory circuit, with the *zero bias* toggle switch 25, in its *bias* position. A comparison of this reading on different good tubes of the same type affords an excellent means for matching tubes for the tuned stages of a radio.

M. The four plate current readings obtained may be compared with tube testing tables, which indicate average relationships in tube characteristics.

been subjected to the rejuvenating process to ascertain the progress of the rejuvenation.

6. If tubes be restored no further rejuvenation is necessary. If not, the process should be repeated until the tube emission is restored or until it is clearly apparent that the tube is worn out or exhausted and will not respond to rejuvenation.

As many as 12 tubes may be rejuvenated at one time by utilizing the tube sockets of a *d.c.* radio, the filament contacts of which are wired in parallel. An improvised bank of sockets may be utilized for connecting the filaments together.

The following procedure should be followed in utilizing the tube sockets of a *d.c.* radio for holding the tubes during rejuvenation:

1. Disconnect the ground lead from the radio.
2. Disconnect the battery or other power supply leads from the radio.
3. Turn all manually controlled rheostats to their full On positions so as to remove rheostat resistances from filament circuits of the radio.
4. Shunt out all automatic filament control devices.
5. Remove one of the tubes from the radio, and insert the analyzer plug in the vacant socket.
6. Fill all other tube sockets of the radio with tubes to be rejuvenated, the total number of tubes not to exceed 12.
7. Close the *d.c.* Fil. switch so as to combine the *analyzer* circuits with the *rejuvenator* circuits.
8. Repeat steps through 6 of the preceding paragraph.

It must be remembered that only tubes of the thoriated filament type which have been paralyzed or over loaded can be restored by rejuvenation. Worn out or exhausted tubes of this type, or tubes of any other type of filament cannot be rejuvenated.

Tube Socket Analyzing.—As the fundamental operating characteristics are practically the same for all radios, for the

purposes of analysis, the circuits of a radio fall into two classifications, namely: the tube socket circuits which are always directly supplied with voltages from the radio power supply system, and may always be subjected to tube socket analysis, and the input (pick-up) and output (audible reproducer) circuits, which may or may not be directly connected to the radio power supply system, and may require the use of some method of testing other than that afforded by tube socket analysis.

The electrical characteristics of the circuits not amenable to tube socket analysis may be determined by their reaction to the *modulated radiator* with the radio in operation. The location of defects in these circuits will be discussed along with the instructions for the use of the *continuity tester*.

If properly connected, each filament, plate, grid and cathode circuit of a radio terminates at a tube socket.

In other words, the radio is built to fit the tube, which is the heart of radio circuits; and the tube circuits constitute the arteries, veins, and nerves of the radio, centering at the tube sockets at which most of the needed information as to the operating characteristics of a radio may be ascertained.

At one time it appeared probable that all tubes would be built on standard UX bases, but the advent of the indirect heater type introduced the UY base. The later appearance of the screen grid tubes introduced another tube element with its contact at the top of the tube. The newer types of radios will probably be built with relatively fewer UX sockets. Until a standard socket arrangement is adopted for all tubes and radios, adapters will be necessary for the interchanging of tubes and sockets. A familiarity with the use of adapters is essential for tube socket analyzing.

Analyzing Adapters.—The diognometer is provided with a plug which requires the use of only one adapter for analytical tests on all radios, including screen grid types and overhead heater filament types, employing UX or UY tube sockets. No tube base adapter is required for placing any UX or UY tube in the sockets of this model.

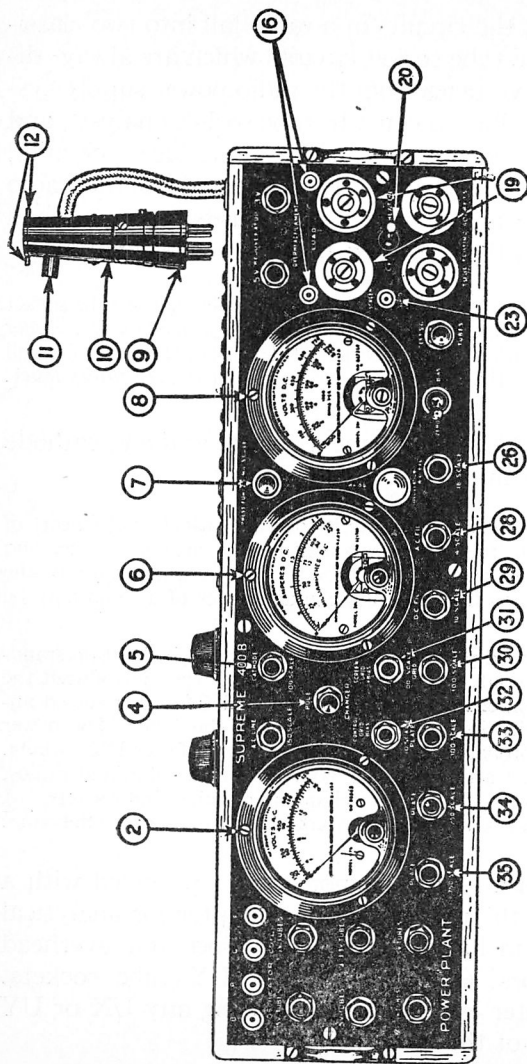


FIG. 7.402—Supreme analyzing radio tube sockets. *PART I—Triode tubes, UX and UY sockets.*

- A. Remove the oscillator coil from the oscillator coil pin jacks 1, and remove all jack plungers and connecting leads from the *diagonizer*;
- B. With the radio to be analyzed turned *off* remove a tube from the radio and place the tube in the *heater* position for UY tubes; accommodate the tube without an adapter;
- C. Throw the UX *heater* switch 20, to the UX position for UX tubes and to the *heater* position for UY tubes;
- D. Insert the analyzer plug 10, using the adapter 9, if required, into the radio tube socket;
- E. Turn the radio *on* and adjust the volume and tuning controls to whatever positions may be recommended by the radio manufacturer for analyzing. The plate current load of the tube will be indicated on the 125 mil. scale of the d.c. milli-ammeter 6, during the analysis. If the reading be less than 25 milli-amperes, the *press* for 25 mil. scale milli-ammeter push button switch 7, may be depressed for a more exact reading on the 25 scale of the meter. If the tube be good, a normal reading on the d.c.

FIG. 7,402.—*Text continued.*

- milli-ammeter 6, generally indicates continuity of all radio circuits terminating at the socket being analyzed;
- F. If it be desired to continue the analysis on the same socket, insert the jack plunger in the *a.c.* filament jack 26, or 28, the scale marking of which least exceeds the filament rating of the tube. The filament voltage should then be indicated on the *a.c.* volt meter 2, scale which corresponds to the closed jack 26 or 28;
- G. Insert the jack plunger in the plate jack 33, 34, or 35, the scale marking of which least exceeds the plate voltage specified for the radio tube socket. The applied plate voltage should then be indicated on the *d.c.* volt meter 8, scale which corresponds to the scale marking of the closed jack 33, 34, or 35;
- H. The negative grid voltage should be indicated on the 100 scale of the *d.c.* volt meter 8, when the jack plunger is placed in the grid jack 30. If the grid of the radio tube socket being analyzed be resistance coupled to the preceding stage, a more accurate reading of the applied grid voltage will be indicated by connecting a test lead between the grid contact of the unoccupied *load socket* 19, and the *grid return* which is usually the grounded chassis of the radio;
- I. A negative cathode bias applied to a UY radio tube socket under analysis should be indicated directly on the 100 scale of the *d.c.* volt meter 8, when the jack plunger is placed in the cathode jack 5. If the *d.c.* volt meter 8, needle backs off scale, depressing the pole changer push button switch 4, affords a direct reading of positive cathode biasing.

NOTE.—*Screen grid tube socket analysis* (fig. 7,402).

A. Remove the oscillator coil from the oscillator coil pin-jacks 1, and remove all jack plungers and connecting leads from the diagnometer;

B. With the radio to be analyzed turned *off* remove a tube from the radio and place the tube in the *load socket* 19, which will accommodate the tube without an adapter;

C. Connect the top control grid contact of the tube with a short clip pin plug lead to the *screen grid* pin jack 23, on the panel;

D. Throw the *UX-heater* switch 20, to the *UX* position for UX tubes and to the *heater* position for UY tubes;

E. Insert the analyzer plug 10, using the adapter 9, if required, into the radio tube socket.

F. Connect the control grid contact lug 11, of the analyzer plug 10, to the control grid clip of the radio tube socket;

G. Turn the radio *on* and adjust the volume and tuning controls to whatever positions may be recommended by the radio manufacturer for analyzing. The plate current load of the tube will be indicated on the 125 mil. scale of the *d.c.* milli-ammeter 6, during the analysis. If the reading be less than 25 milli-amperes, the *press for 25 mil. scale* milli-ammeter push button switch 7, may be depressed for a more exact reading on the 25 scale of the meter. If the tube be good, a normal reading on the *d.c.* milli-ammeter 6, generally indicates continuity of all radio circuits terminating at the socket being analyzed;

H. If it be desired to continue the analysis on the same socket, insert the plunger in the *a.c.* filament jack 26, or 28, the scale marking of which least exceeds the filament rating of the tube. The filament voltage should then be indicated on the *a.c.* volt meter 2, scale which corresponds to the closed jack 26, or 28. If the filament of the radio tube socket be supplied with a direct current voltage, the *d.c.* filament jack 29, should be used instead of an *a.c.* filament jack 26, or 28, for indicating the *d.c.* filament voltage on the 10 scale of the *d.c.* volt meter 8;

I. Insert the jack plunger in the plate jack 33, 34, or 35, the scale marking of which least exceeds the plate voltage specified for the radio tube socket. The applied plate voltage should then be indicated on the *d.c.* volt meter 8, scale which corresponds to the scale marking of the closed jack 33, 34, or 35;

A snap catch is employed on this plug to prevent the separation of the adapter from the plug when inserted in a tube socket. Special pin plug clip leads are used for testing screen grid tubes and for testing overhead heater filament tubes.

A pole changer switch must be used in connection with the adapter. Grid and plate voltages should be read with the pole changer in its normal position and re-read with the pole changer depressed. Unless no reading is obtained in either case, the lowest reading obtained should be used as the correct reading. The pole changer switch should be depressed when the *d.c.* volt meter backs off scale when attempting to read *d.c.* filament voltages.

The adapter should be used for placing UX tubes in the load socket when analyzing *a.c.* radios, and when analyzing *d.c.* radios in which the negative filament terminals are adjacent to the plate terminals. Leave the pole changer switch in its normal position for reading the filament voltages.

Voltage Tests, Circuits Unloaded.—*No load* filament, plate and grid voltage tests may be made with all tubes removed from the sockets of parallel filament radios where all of the voltages are supplied from batteries. *No load* readings may be compared with the *load* readings for ascertaining the extent of battery exhaustion. On all other radios, except those employing series filaments, *no load* filament and plate voltage readings should be taken with only one of the tubes out of the circuits.

No load grid readings need not be undertaken except where a C battery is used: In battery types of radios where no C voltage is employed, continuity of the grid circuit may be determined by changing the position of the pole changer switch so as to read the filament voltage across the grid circuit with the *grid* switch closed.

NOTE.—*Continued.*

J. The negative control grid bias should be indicated on the 10 scale of the *d.c.* volt meter 8, when the jack plunger is placed in the control grid jack 32;

K. The positive screen grid bias should be indicated on the 100 scale of the *d.c.* volt meter 8, when the jack plunger is placed in the screen grid jack 31;

L. A negative cathode bias applied to a UY radio tube socket under analysis should be indicated directly on the 100 scale of the *d.c.* volt meter 8, when the jack plunger is placed in the cathode jack 5. If the *d.c.* volt meter 8, needle back off scale, depressing the pole changer push button switch 4, affords a direct reading of positive cathode biasing.

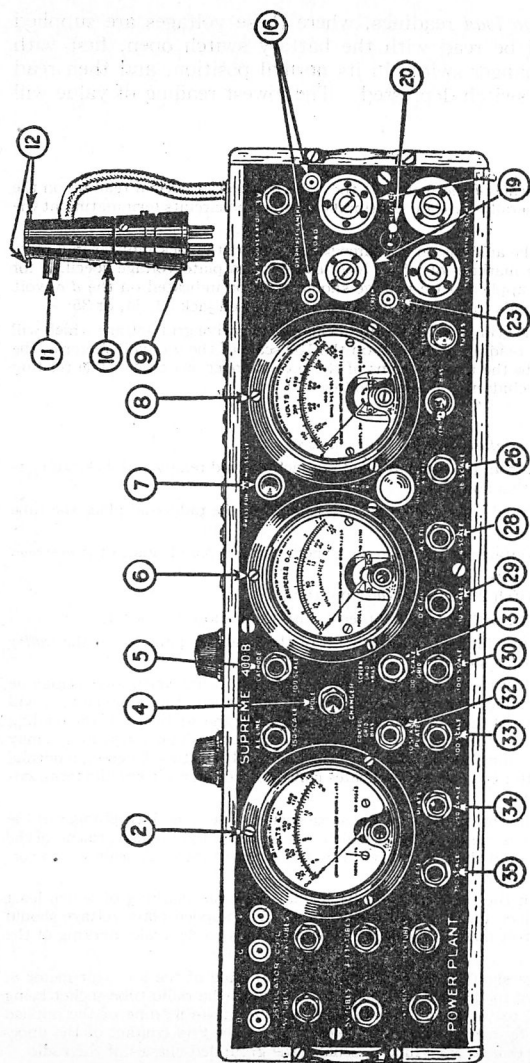


FIG. 7,403—Supreme analyzing radio tube sockets. **PART 2—Triode tubes, UX and UY d.c. filament.**

- A. Remove the oscillator coil from the oscillator coil pin jacks 1, and remove all jack plungers and connecting leads from the diagrammer;
- B. With the radio to be analyzed turned *off*, remove a tube from the radio and place the tube in the *load socket* 19, which will accommodate the tube without an adapter;
- C. Throw the *UX heater* switch 20, to the *UX* position. Insert the analyzer plug 10, using the adapter 9, if required, into the radio tube socket;
- D. Insert the jack plunger in the *d.c.* filament jack 29;
- E. Turn the radio *on*. If the *d.c.* volt meter 8, needle backs off scale, depress the pole changer push button switch 4, while adjusting the radio filament controls, if any, for an indication on the 10 scale of the *d.c.* volt meter 8, of the rated filament voltage of the tube. The plate current load of the tube will be indicated on the 125 mil. scale of the *d.c.* milli-ammeter 6 during the analysis. If the reading be less than 25 milli-amperes, the *press* for 25 mil. *scale* milli-ammeter switch 7, may be depressed for a more

All grid and plate *no load* readings, where these voltages are supplied with batteries, should be read with the battery switch open, first with the testing set pole changer switch in its normal position, and then read with the pole changer switch depressed. The lowest reading of value will

FIG. 7,403.—Text continued.

exact reading on the 25 mil. scale of the meter. If the tube be good, a normal reading on the d.c. milli-ammeter 6, will generally indicate continuity of all radio circuits terminating at the socket being analyzed;

- F. If it be desired to continue the analysis on the same socket, insert the jack plunger in a plate jack 33, 34, or 35, the scale marking of which least exceeds the plate voltage specified for the radio tube socket. The applied plate voltage should then be indicated on the d.c. volt meter 8, scale which corresponds to the scale marking of the closed jack 33, 34, or 35;
- G. Insert the jack plunger in the grid jack 30, for observing the negative grid voltage which will be the lower of two separate readings indicated on the 100 scale of the d.c. volt meter 8, the two readings corresponding to the two positions of the pole changer switch 4. The reading of the lower value will not include the filament voltage.

NOTE.—Top heater tube socket analysis (fig. 7,403).

A. Remove the oscillator coil from the oscillator coil pin jacks 1, and remove all jack plungers and connecting leads from the diagnetometer;

B. With the radio to be analyzed turned off remove a tube from the radio and place the tube in the UX load socket 19;

C. Connect the top heater contacts of the tube with short clip pin plug leads to the overhead filament pin jacks 16, on the panel;

D. Throw the UX-heater switch 20, to the heater position;

E. Insert the analyzer plug 10, without the adapter 9, into the radio tube socket;

F. Connect the top heater tube filament contacts 12, of the analyzer plug 10, to the trolley filament contacts of the radio tube socket;

G. Turn the radio on and adjust the volume and tuning controls to whatever positions may be recommended by the radio manufacturer for analyzing. The plate current load of the tube will be indicated on the 125 mil. scale of the d.c. milli-ammeter 6, during the analysis. If the reading be less than 25 milli-amperes, the press for 25 mil. scale milli-ammeter push button switch 7, may be depressed for a more exact reading on the 25 scale of the meter. If the tube be good, a normal reading on the d.c. milli-ammeter 6, generally indicates continuity of all radio circuits terminating at the socket being analyzed;

H. If it be desired to continue the analysis on the same socket, insert the jack plunger in the a.c. filament jack 26, or 28, the scale marking of which least exceeds the filament rating of the tube. The filament voltage should then be indicated on the a.c. volt meter 2, scale which corresponds to the closed jack 26, or 28;

I. Insert the jack plunger in the plate jack 33, 34, or 35, the scale marking of which least exceeds the plate voltage specified for the radio tube socket. The applied plate voltage should then be indicated on the d.c. volt meter 8, scale which corresponds to the scale marking of the closed jack 33, 34, or 35;

J. The negative grid voltage should be indicated on the 100 scale of the d.c. volt meter 8, when the jack plunger is placed in the grid jack 30. If the grid of the radio tube socket being analyzed is resistance coupled to the preceding stage, a more accurate reading of the applied grid voltage will be indicated by connecting a test lead between the grid contact of the unoccupied load socket 19, and the grid return which is usually the grounded chassis of the radio.

not include the filament voltage and should be recorded as the correct grid or plate voltage respectively.

Load Tests.—The load test of any device is the most reliable test. A comparison of the *load* test of any electrical device with its *no load* test is a fairly reliable index to the internal resistance of the device.

When a tube is placed in the *load socket* during analysis with the radio in operation, the current drawn by the tube will be shown on the milli-ammeter. This reading may be compared with the tables published by tube manufacturers.

If there be a radical departure from the specified current reading it indicates a defective tube, or improper relation between the B and C voltage of the radio. The latter is not an unusual trouble where socket power devices are attached to radios originally designed for battery operation. Wherever this trouble is encountered, the B voltage should be adjusted to the proper value for the C voltage used. Otherwise the tubes will be subjected to strenuous usage, and the reproduction will not be satisfactory in quality.

When taking voltage readings, it may be noticed that the milli-ammeter may show a slight deflection, indicating the load of the volt meter, which, with the 1000 *ohm per volt* volt meter, will be 1 milli-ampere at full scale volt meter deflection. All load readings taken with the testing set will be accurate within about 2%, this slight variation being accounted for by the losses encountered in the analyzing cord leads.

Setting up the Analyzer.—The following procedure constitutes the preliminary procedure for putting the *analyzer* circuits in operation:

1. Remove the oscillator coil from its prescribed operating position.
2. Open all switches.
3. Disconnect the *a.c.* supply cord and clear all jacks from contact with any electrical conductor which might be grounded or directly connected to the common alternating current supply system, thereby avoiding any possibility of electrical harm to the testing set or to the radio.
4. Open the power supply switch of the radio to be analyzed.

Filament Circuit Analysis.—While analyzing, the UX heater switch, located between the testing set tube sockets, is thrown to UX position for analytical tests from radio tube sockets which do not utilize tubes with independent cathode emitters. For all tubes with independent cathode emitting elements, including *top heater* tubes, the switch is thrown to the *heater* position.

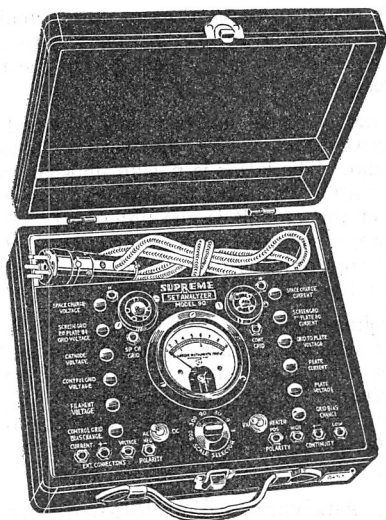


FIG. 7,404.—Supreme set analyzer. It makes available a great number of tests and provides 79 readings.

A special plug adapter is used for plugging into UY sockets. With the plug in the first socket and the tube laid aside, close the proper *Fil.* switch which will measure the filament voltage.

If testing in a *d.c.* tube socket, the needle of the *d.c.* volt meter may back off the scale, and the pole changer should be depressed to obtain correct readings; this will indicate the direct current voltage available at the filament terminals, and if the rheostat be turned on full and the other tubes removed, it will also indicate the *no load* A battery voltage.

If testing in an *a.c.* socket, the reading will indicate the voltage available on open circuit. The reading obtained in either case should be recorded. With the plug still in the radio socket, place the tube in the *load socket* of the *analyzer* and again read the filament voltage. It is important that this reading be close to that for which the tube is rated; if it is above the rated voltage, the life of the tube will be correspondingly short, whereas if it is very much below the rated voltage, proper results will not be obtained. If an adjustment be possible with the radio being analyzed, proper adjustment should be made.

The best results will be obtained with the filament voltages at, or just below, their rated voltage.

Failure to obtain any filament reading will indicate an open or shorted filament circuit, with the following causes:

A battery exhausted	Open primary or low voltage secondary of <i>a.c.</i> power transformer
Open rheostat	
Poor connection	Blown fuse
Defective filament switch	Poor socket contacts

Plate Circuit Analysis.—Plate voltage readings may be taken with or without the tube in the *load socket*. Before taking either voltage, open the *Fil.* switch.

Close one of the *plate switches* using the one which will best accommodate the voltage to be read and at the same time give a good discernible reading. The reading obtained with the tube in the *load socket* will be less than the reading obtained without the circuit loaded. This difference is occasioned by the internal resistance current drop of the B supply device, and it is, to a certain extent, except in detector sockets, an index to the condition of the apparatus supplying the plate voltage. If this voltage drop materially exceed 1 volt per milli-ampere drawn by the tube, the B batteries should be replaced, or the rectifying tube in the plate supply device should be replaced.

If means be available for adjusting the voltage in socket power devices, the plate voltage should be adjusted to that specified for the particular tube and the particular socket which is being tested. The readings obtained should be recorded.

The plate current under load conditions is a very good index to the operating condition of the plate circuit, the current being the result of the voltages applied to the grid and plate circuits.

Decreasing the grid voltages has more effect, other factors being equal, on increasing the plate current than may be had by increasing the plate voltage.

Failure to obtain proper readings may be caused by any of the following troubles:

- | | |
|-------------------------------------|--------------------------------|
| Weak or exhausted B batteries | Shorted by pass condenser |
| Open primary winding of transformer | Loose connection |
| Open series plate resistor | Loose or broken socket contact |
| Defective rectifier tube | |

Grid Circuit Analysis.—In radios employing batteries for supplying C bias, practically the same reading should be obtained without the tube in the *load socket* as with the tube in the *load socket*.

This is because the grid circuit has practically no current flow.

In radios employing biasing resistors, the correct voltage reading on the bias can be had only when the tube is in the *load socket* and the bias voltage should be read with the *grid* switch closed for the highest scale of the *d.c.* volt meter which will afford a discernible reading.

With the plug in the radio socket and the tube in the *load socket*, closing the *grid* switch will throw the volt meter across the grid and one of the filament contacts of the radio tube socket. The pole changer switch should be closed for each reading, and the lowest reading should be taken as the correct bias reading, as one of the readings may include the voltage of the filament.

In *d.c.* radios, a reversed A battery may be indicated by the backing off scale of the *d.c.* volt meter needle when the *grid* switch is closed.

If no reading be obtained when the *grid* switch is closed after having tried the pole changer in both of its positions, the following sources of trouble should be investigated, except in radios employing synchrophase circuits; *a*, Open transformer, low voltage secondary; *b*, Open grid suppressor; *c*, Open grid bias resistor; *d*, Poor grid contact in tube socket.

When analyzing from the detector socket of a radio, it will usually be found that a very low voltage reading is obtained.

This is due to the fact that a grid leak is usually employed in series with the grid for grid leak detection, and is of such high resistance that it lowers the reading of grid voltage. The grid leak resistance may be temporarily shunted if it be desired to get a true grid voltage reading.

Cathode Circuit Analysis.—A cathode switch is provided for obtaining voltage readings of the cathode bias employed in 4 and 5 element tubes.

Cathode circuits are rarely the source of radio troubles, but the readings obtained should be recorded and compared with the specifications for the tube and tube socket analyzed. No reading, where cathode biasing resistors are known to be employed would indicate an open resistor, and a low reading would indicate a partially shorted resistor. If no means be available for reading the cathode bias, a defective bias would probably be indicated by excessive hum.

Screen Grid Analysis.—This is accomplished by plugging into the socket to be analyzed, connecting the clip, which ordinarily connects to the top of the tube, to the large control grid lug close to the top of the analyzing plug.

The screen grid tube is placed in the *load socket* in the usual manner, and one of the clip pin plug leads is used for connecting the control grid contact of the tube to a corresponding pin jack on the instrument panel.

Overhead Heater Filament Analysis.—The procedure is similar to that for *screen grid* analysis, except that the *trolley* contacts are connected to the *trolley* contact lugs on the analyzer plug, and two clip pin plug leads are used for connecting the filament contacts of the tube to corresponding *overhead filament* pin jacks on the instrument panel.

Distortion Tests.—With analyzer plugged into last audio amplifying stage, with all testing set switches open, the action of the milli-ammeter is a fair index to the degree of distortion in the audio circuits. The ideal condition is to have the needle steady regardless of the signal fluctuations.

If the needle deflect upward with the signal impulses, it is an indication that the C voltage is too high for the B voltage being used, or that the B voltage is too low for the C voltage being used.

If the needle deflect downward for each signal impulse, it is an indication that the C voltage is too low for the B voltage being used, or that the B voltage is too high for the C voltage being used. This test, of course, should only be undertaken when it is known that all of the tubes in the radio are in normal operating condition. The adjustment, if any is possible with the radio being analyzed, will be obvious from the above description. The technical analysis of the causes of the distortion involves a study of the graphs plotting the characteristics of tubes, which is a very long drawn out discussion.

Analysis Charts.—These charts are arranged in duplicating pads and are very useful for recording the readings obtained during tube socket analyzing.

A copy of each chart may be kept for future reference on any radio. Radical readings will be indicated by comparison with other charts on the same type of radio. These charts have space provided for the *power plant* tube tests which should precede the analysis of any radio.

Input Circuit.—After completing the analysis of the tube circuits of a radio, the service man should turn his attention to the circuits of the radio system which are not amenable

to tests by means of the tube socket analyzing methods just described.

The efficiency of these circuits can best be determined by tuning the radio to a modulated radio frequency signal known to exist within pick up distance of the radio.

The *modulated radiator* of the testing set affords an excellent means for setting up the modulated radio frequency signal for these tests. The necessary procedure for setting up the *modulated radiator* was covered at the beginning of this chapter.

The pick up circuit should first be checked as to efficiency.

This circuit consists of the aerial and the ground or counterpoise system, or of a loop or large pick up coil, or of two or more capacity areas, or of a combination of any two of these systems, coupled to the grid circuit of the first tube of the radio. The continuity of a loop aerial may be determined by socket analysis where the loop circuit is directly coupled to the first radio tube, but it is sometimes found that loop aerials are capacitively coupled to the tube circuit, in which case the continuity of the pick up loop cannot be determined by tube socket analysis.

Where the pick up circuit consists of an aerial and ground or counterpoise, no voltage is applied between the two, and even where the antenna is connected directly to the grid of the first tube, an open or shorted pick up circuit cannot be detected by tube socket analysis.

The antenna of the radio being tested should conform as nearly as practicable to the specifications of the manufacturer of the radio.

A comparative test of the pick up capabilities of the antenna may be had by tuning the radio to the *modulated radiator*, and then disconnecting the antenna. The signal strength should fall off when the antenna is disconnected, or a loud *clicking* sound should be emitted from the loud speaker when the aerial is disconnected and tapped on the antenna binding post of the radio. The absence of a strong *clicking* when this is done with the volume control of the radio at its normal setting, usually indicates an inefficient aerial circuit.

The ground circuit should be checked in a similar manner, although there should be a very perceptible drop, amounting to about 50%, in audibility when the ground is disconnected. If there be but slight change in signal strength with the ground lead removed, new grounds should be

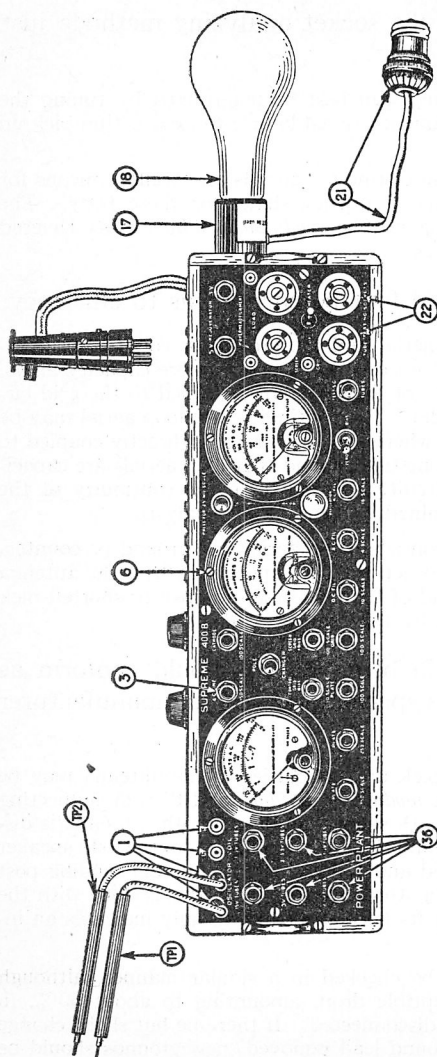


FIG. 7,405—Supreme continuity tests. *Medium and high resistances.*

Medium resistances:

- A. Remove any jumpers or test leads which may have been left connected to the instrument, open all jack switches on the panel, and clear the analyzer plug 10, from contact with any electrical conductor which may be grounded or connected to the common a.c. supply system;
- B. Insert the polarized series socket adapter 17, with a 100 watt Mazda lamp 18, in the receptacle on the end of the instrument tray. If any device other than a 100 watt Mazda lamp 18, should ever be used in the series socket adapter 17, the milli-ammeter 6, might be harmed or show incorrect readings;
- C. Connect the supply plug 21, to a convenient a.c. supply outlet;
- D. Close the a.c. line jack 3, and observe the supply voltage on the 150 scale of the a.c. volt meter 2;
- E. Insert test probes TP1, and TP2, in the two left side B, and P, oscillator coil pin jacks 1;
- F. Place a thermionic rectifier tube, such as the '81 or '80 type, in the UX tube testing socket 22;
- G. Close a power plant jack 36, the voltage marking of which corresponds to the filament voltage rating of the tube used;
- H. Closing the circuit with the free ends of the test leads will cause the plate current of the tube to be shown on the milli-ammeter, indicating continuity of the testing set plate circuit with the external circuit under test. This test should not be undertaken on

tried on the radio. A high resistance ground is a very common cause of low audibility. In localities where one side of the *a.c.* supply system is grounded, the ground lead of a radio may be determined by connecting a lamp or *a.c.* volt meter between the ground lead and the ungrounded side of the line. This is also an excellent means for determining whether or not the antenna is shorted to the ground lead. This method also affords a very convenient means for differentiation between the antenna and ground leads when it is not convenient to differentiate them by visual inspection.

FIG. 7,405.—*Text continued.*

- a grounded radio or other grounded apparatus. This precaution is necessary for meter protection where the protective lamp 18, may be in the grounded side of the *a.c.* supply system;
- I. This hook up may be used for measuring medium resistances, as outlined on pages 4,615 and 4,617.

NOTE.—Continuity tests. High resistances (fig. 7,405). For determining continuity through high ohmic resistances in either reactive (inductive and capacitive) or non-reactive circuits, and for the testing of condensers, but without the use of any battery, the following procedure is recommended:

- A. Remove any jumpers or test leads which may have been left connected to the instrument, open all jack switches on the panel, and clear the analyzing plug 10, from contact with any electrical conductors which may be grounded or connected to the common *a.c.* supply system;
- B. Insert the polarized series socket adapter 17, with a 100 watt Mazda lamp 18, in the receptacle on the end of the instrument tray. If any device other than a 100 watt Mazda lamp 18, should be used in the series socket adapter 17, the milli-ammeter 6, might be harmed;
- C. Connect the supply plug 21, to a convenient *a.c.* supply outlet;
- D. Place an '80 tube in the *UX* tube testing socket 22;
- E. Insert the grooved rejuvenator plunger to the half way *aging* position in the 3*v.* rejuvenator jack 15. This will apply a filament voltage of about 3.3 volts to the '80 tube;
- F. Insert a jack plunger in the *a.c. line jack* 3. The supply voltage should then be indicated on the *a. c.* volt meter 2;
- G. Insert a second jack plunger in the *control grid bias* jack 32;
- H. Connect a jumper between the *screen grid* 23, pin jack on the panel and one of the 500,000 ohm pin jacks I, on the back of the instrument tray;
- I. Connect a jumper between the B and P oscillator coil pin jacks 1, on the panel;
- J. Connect a test probe to the unoccupied 500,000 ohm pin jack K, on the back of the instrument tray;
- K. Connect a test probe to the common *a.c.* pin jack L, on the back of instrument tray;
- L. While touching the free ends of the test probes together, adjust the 500,000 ohm control knob Y, located on the back of the instrument tray, for a full scale needle deflection on the *d.c.* volt meter 8. The variable resistance has the effect of increasing the internal resistance of the 10 scale of the *d.c.* volt meter to a value of about 50,000 ohms for accommodating the applied rectified effective voltage of about 50 volts;
- M. This test should not be undertaken on a grounded circuit. The common *a.c.* pin jack L, on the back of the instrument tray is connected to one side of the primary winding of the power transformer during this test, and grounding the test probe connected to this pin jack would probably short circuit the *a.c.* supply system in localities where one side of the *a.c.* supply system is grounded.

Lightning arresters should always be checked for shorted electrodes.

Stapling the antenna and ground leads together on base boards is a very common source of trouble with antenna ground shorts.

Output Circuit.—This consists of the loud speaker, or other

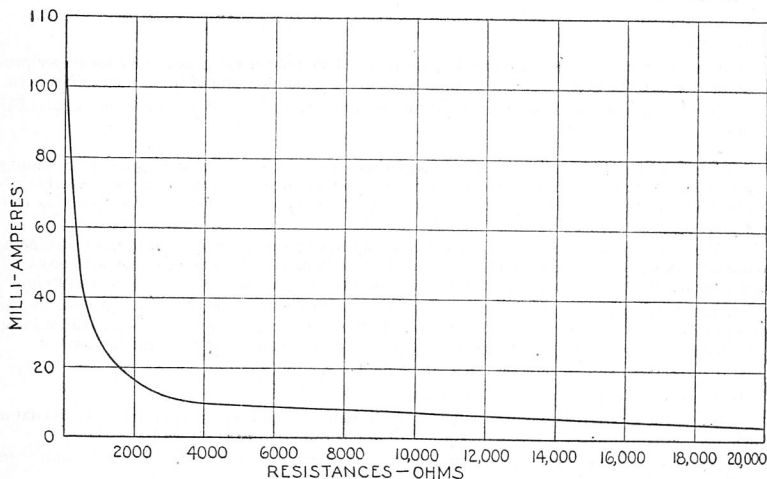


FIG. 7,406.—Resistance current curve plotted with the *continuity tester*, set up as outlined on page 4,615, utilizing an X-80 tube having a plate reading of 100 milli amperes with test probes touched together; that is, with full plate current load. *Example!* the 100 scale of 1,000 ohms per volt *d.c.* volt meter of the *Diagnometer* is used with a 45 volt B battery for measuring an unknown resistance. The internal resistance of the volt meter with this scale is 100,000 ohms. A reading of 30 volts is obtained across the battery, and a reading of 20 volts is obtained with the volt meter, battery, and unknown resistance connected in series.

NOTE.—In fig. 7,406 the formula to be used is:

$$R = r \left(\frac{V_1}{V_2} - 1 \right)$$

where R = Unknown resistance r = Internal resistance of volt meter; V_1 = Unloaded voltage of battery or batteries in series, and V_2 = Reading of volt meter when in series with battery or batteries and unknown resistance.

Substituting: $30 \div 20 = 1.5$; $1.5 - 1 = 0.5$; $.5 \times 100,000 = 50,000$ ohms.

device for audible reproduction, and the circuit which couples it to the last audio frequency stage of the radio.

In most of the earlier types of radios the loud speaker is directly coupled in series with the plate circuit of the last audio tube, and the continuity of the output circuit in such radios may be determined by tube socket analysis.

In most of the more recent models of radios, wherein the last audio plate voltage exceeds 135 volts, the loud speaker is usually indirectly coupled to the last audio stage, and a test of the output circuit cannot be made from a radio tube socket. In either of these types, the efficiency of the output circuit can best be determined by tuning in signals on the radio. If no other apparent defects exist in the radio system, and the loud speaker do not perform satisfactorily, the loud speaker circuits can be tested for opens and shorts with the *continuity tester*.

Loud speaker windings should not be required to carry a current load in excess of that specified by the speaker manufacturer.

In the absence of specifications to the contrary, the last audio or power tube chosen and the grid and plate voltages applied thereto should be such that the speaker load should not exceed 10 milli-amperes. If the plate current of the last audio-amplifying tube exceed this value, some type of filter circuit is generally required to protect the loud speaker windings from overload currents. A '71-A tube should not be substituted for a '12-A in an audio stage without changing the grid bias voltage to correspond to the tube to be used. This change in grid bias voltage must not affect the grid bias voltage of other tubes.

Some radios were designed for using a '01-A tube as the first audio amplifier, and a '12-A as the second audio, using 135 volts plate voltage and 9 volts grid bias on both tubes. If the '12-A be replaced with a '71-A, the 9 volts grid bias would be incorrect for the '71-A, while a change to 27 volts grid bias for the '71-A would place an incorrect bias on the '01-A used as the first audio tube. Where no filter system is used, the polarity of the loud speaker should be checked with a *d.c.* meter, as a reversed polarity will eventually weaken the magnetism of the speaker magnets.

Putting the Continuity Tester in Operation.—The *continuity tester* is especially adaptable for testing the input and output

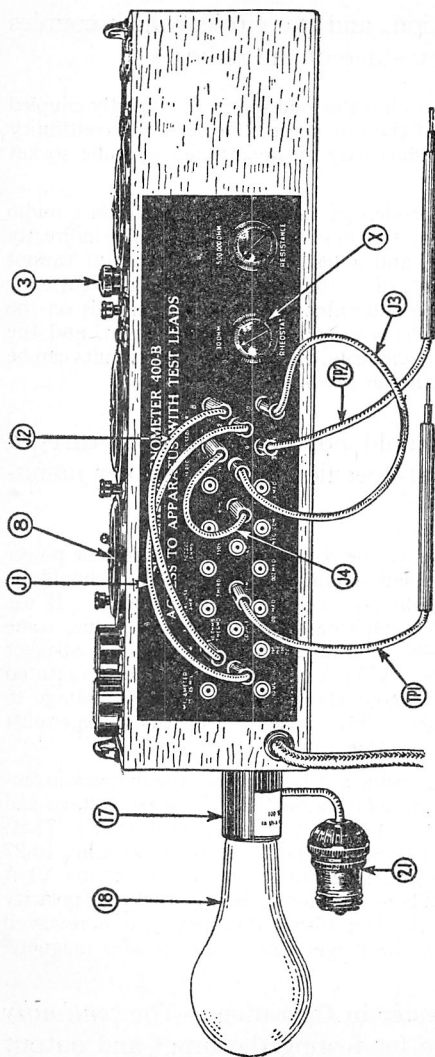


FIG. 7,407—Continuity tests. *Low resistances.*

- A. Remove any jumpers or test leads which may have been left connected to the instrument, open all jack switches on the panel, and clear the analyzer plug 10, from contact with any electrical conductors which may be grounded or connected to the common a.c. supply system;
- B. Insert the polarized series socket adapter 17, with a 100 watt Mazda lamp 18, in the receptacle on the end of the instrument tray. If any device other than a 100 watt Mazda lamp 18, should ever be used in the series socket adapter 17, the milli-ammeter 6, might be harmed;
- C. Connect the supply plug 21, to a convenient a.c. supply outlet;
- D. Connect jumpers J1, J2, J3, and J4, to the pin jacks as indicated;
- E. Insert the jack plunger in the a.c. line jack 3;
- F. Connect test probes TP1, and TP2, to the pin jacks as indicated;
- G. With test probes touched together, adjust 30-ohm rheostat control knob X, for full scale reading on the d.c. volt meter 8. The approximate uncalibrated range of the meter in this resistance test is from 0.1 to 25 ohms, depending on the a.c. supply voltage. It is very useful in locating defective soldered joints, shorted variable condenser plates without disconnecting r.f. coils, and for checking the center tap of filament resistors or for indicating other low resistance values.

circuits of a radio when these circuits are not supplied with any voltage from the radio power supply system. Care must be exercised, however, not to allow one of the test probes of the testing set to come in contact with a grounded conductor.

With the *modulated radiator* in operation, the following steps are required for putting the *continuity tester* in operation.

1. Disconnect apparatus to be tested from both the *a.c.* line and all grounded objects. This is a very necessary precaution for meter protection.
2. Remove the oscillator coil from its prescribed pin jack position.
3. Plug two test cords in the two left side (B and P) oscillator coil pin jacks.
4. Place a thermionic rectifier tube, such as the '81 or '80 or other heavy current tube, in one of the *tube testing sockets*.
5. Close the *power plant* jack switch, the voltage marking of which corresponds to the filament voltage specified for the tube used.
6. Closing the circuit with the free ends of the test leads will cause the plate current of the tube to be shown on the milli-ammeter, indicating continuity of the testing set plate circuit with the external circuit under test.

Any three or four element tube capable of showing comparatively good discernible plate current readings, such as the '71-A, '12-A, '26 and '01-A types, may be used with its corresponding *power plant* switch closed instead of rectifying tubes for this test, by connecting a jumper between the two oscillator coil pin jacks which are not occupied with the test probe leads.

The *continuity tester* is adaptable for testing the input and output circuits of a radio when these circuits are not supplied with any voltage from the radio power supply system so that they may be tested with the *analyzer* from tube sockets. It is also useful for testing for loose contacts in circuits.

Synchronizing Procedure.—Having determined that the tubes, tube circuits, and the input and output circuits of a radio are in their proper conditions, the next step in servicing should be to check the synchronous relation of the tuning condensers. The two methods of obtaining a meter indication of resonance are shown in fig. 7,408.

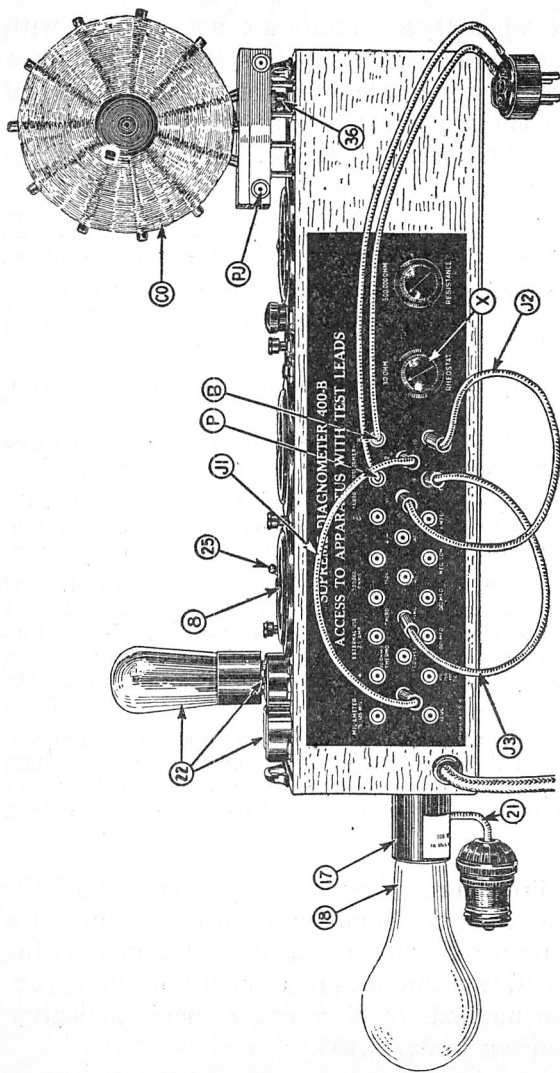


FIG. 7,408—Supreme synchronizing without meters. *Thermo-couple output meter synchronizing.*

Letters in parentheses refer to fig. 7,397, page 4,588.

- A. Put the modulated oscillator in operation as in fig. 7,398;
- B. Set the 30-ohm rheostat control (X), in its approximate center position;
- C. Connect jumpers (J1), (J2), and (J3), to the pin jacks as indicated;
- D. Connect the synchronizing (plate break) adapter terminals to the P and B, pin jacks, on the back of the instrument tray.
(When synchronizing radios designed for magnetic speakers, the loud speaker terminals of the radio may be connected to the P and B, pin jacks, instead of using the synchronizing (plate break) adapter.)

FIG. 7,408.—*Text continued.*

- E. Remove a tube from the last audio stage of the radio and insert the tube in the adapter. Place the adapter in the vacant audio tube socket;
- F. Rotate the tuning knob of the radio while adjusting the 30-ohm rheostat for the desired needle deflection which will occur on the *d.c.* volt meter 8, as each harmonic of the modulated oscillator is *tuned in* on the radio. A maximum needle deflection indicates resonance of the radio with the modulated oscillator. When using the synchronizing (plate break) adapter in push pull stages, the needle deflection of the meter may be increased on some radios when the push pull socket not occupied by the adapter is left vacant during the synchronizing operations;
- G. Adjust the coupling between the diagnetometer and the radio for the desired signal strength;
- H. Adjust each tuning condenser for a maximum reading on a signal between 1,000 and 1,500 kilocycles, or between whatever other frequency limits specified by the manufacturer of the radio.

NOTE.—*Thermo-couple output meter measurements* (fig. 7,408). By omitting sections A, F, G, H, in fig. 7,403, this hook up may be used for comparing the gain of any two audio amplifiers in the following manner;

- A. Remove the aerial and ground leads from the radio under test;
- B. Remove the detector tube of the radio;
- C. With suitable test leads, apply an audio frequency signal to the plate and cathode contacts of the vacant detector socket. For these comparisons, the ordinary 110 volt 60 cycle power supply may be used for supplying the audio signal voltage;
- D. The same tests may be accomplished with the *a.c.* volt meter by similar modifications of the following procedures.

NOTE.—*Low impedance output a.c. volt meter synchronizing* (fig. 7,408).

- A. Put the modulated oscillator in operation in the manner outlined in fig. 7,398;
- B. Connect the *plus or minus a.c. L*, and the 1 *mfd. U*, external pin jacks of the diagnetometer to the voice coil terminals of the radio;
- C. Close the 4 volt *a.c.* filament jack 28;
- D. Throw the *UX-heater* toggle switch 20, to the *heater* position;
- E. Rotate the tuning control of the radio. A decided *a.c.* volt meter 2, deflection will occur as each harmonic of the modulated oscillator is *tuned in* on the radio. A maximum needle deflection indicates resonance of the radio with the modulated oscillator;
- F. Adjust the coupling between the diagnetometer and the radio for the desired signal strength;
- G. Adjust each tuning condenser for a maximum reading on a signal between 1,000 and 1,500 kilocycles, or between whatever other frequency limits specified by the manufacturer of the radio.

NOTE.—*High impedance output a.c. volt meter synchronizing* (fig. 7,408).

- A. Put the modulated oscillator in operation in the manner outlined in fig. 7,398;
- B. Connect a jumper between the *third winding H*, and *plus or minus a.c. L*, external pin jacks;
- C. Connect a jumper between the 30 *ohm E*, and 1 *mfd. U*, external pin jacks;
- D. Throw the *UX-heater* toggle switch 20, to the *heater* position;
- E. Close the 4 volt *a.c.* filament jack 28;
- F. Connect the synchronizing (plate break) adapter terminals to the P, and B, pin jacks on the back side of the instrument tray. When synchronizing radios designed for magnetic speakers, the loud speaker terminals of the radio may be connected to the P, and B, external pin jacks, instead of using the synchronizing adapter.

Volt Meter, A.C. Low Scales.—The pin jack connections of the testing set afford external access to a low scale of the *a.c. volt meter*, the scale range being determined by the closed *a.c.* filament jack. The current required for full scale deflection on each of the low ranges is approximately 100 milli-amperes.

Neutralizing Procedure.—The neutralization of tuned radio frequency radios provided with adjustable neutrodon condensers may be accomplished as follows:

1. Place the *modulated radiator* in operation in the manner previously described.
2. Connect antenna and ground to radio to be neutralized.
3. Put radio in operation at its maximum volume.
4. Tune the radio to a strong modulated harmonic at a frequency between 1,350 and 1,500 kilocycles, or between whatever other frequency limits prescribed by the manufacturer of the radio to be neutralized.
5. Move testing set far enough away from the radio so that inductive reactions will not occur between the radio and the testing set; but if the signals cannot be picked up, move the instrument closer to the radio, use a better oscillating tube, or use an insulated coupling lead brought in close proximity to the oscillator coil and the antenna lead in of the radio.
6. Adjust each neutrodon for maximum signal strength so as to increase pick up.

NOTE.—FIG. 7,408.—*Continued.*

G. Remove a tube from the last audio stage of the radio and insert the tube in the adapter. Place the adapter in the vacant audio tube socket;

H. Rotate the tuning knob of the radio. A decided *a.c.* volt meter 2, deflection will occur as each harmonic of the modulated oscillator is *tuned in* on the radio. A maximum needle deflection indicates resonance of the radio with the modulated oscillator. When using the synchronizing adapter in push pull stages, the needle deflection of the meter may be increased on some radios when the push pull socket not occupied by the adapter is left vacant during the synchronizing operations;

I. Adjust the coupling between the diagnetometer and the radio for the desired signal strength;

J. Adjust each tuning condenser for a maximum reading on a signal between 1,000 and 1,500 kilocycles, or between whatever other frequency limits specified by the manufacturer of the radio.

7. Remove the tube of the radio frequency stage nearest the detector.
8. If the radio be wired with its tube socket filament connections in parallel, place the tube in the *neutralizing adapter* and replace in the radio socket; or substitute a *dummy* tube (*i.e.*, a good tube with one of the filament prongs cut off) of the same type in the socket.
9. If the radio be wired with its tube socket filament connections in series, temporarily strap the filament prongs of the tube together and replace it in its socket.
10. If the signal remain audible, the internal capacity of the cold tube is probably by-passing the signals which should be tuned to maximum strength.
11. Slowly adjust the neutrodon which corresponds to the cold tube stage, using a fibre wrench or fibre screw driver to minimize body capacity effects, until the signal disappears entirely or is reduced to minimum audibility.
12. The stage in which the cold tube is located will then be neutralized, and the cold tube should be removed and replaced by the original tube.
13. Proceed in a similar manner with each of the stages in order until all of the radio frequency stages are neutralized.

The degree of accuracy attained when using a *dummy* tube for neutralizing parallel filament radios is determined by the degree of uniformity of the internal capacities of tubes.

It cannot be expected that all tubes, even of the same type, will have the same internal capacity as the *dummy* tube chosen for neutralizing purposes. It is frequently found that an adjustment for neutralizing one tube is an improper adjustment for another tube.

Calibrating.—Every broadcasting station operates upon a particular frequency, assigned to it by the Federal Radio Commission. Each channel is designated by the middle frequency.

With the aid of a graph, plotted to a few representative dial settings corresponding to known frequencies, it is possible to tune to any desired broadcasting station within the pick up distance of the radio, when the frequency at which that station broadcasts is known.

To make a dial calibration graph, tune to at least five or six stations at settings throughout the complete range of the tuning dial.

While receiving each station, listen for the announcer's statement of the frequency that his station is using. Then record this frequency and the corresponding dial setting. With this data plot a curve and from the curve the dial settings for a desired station may be obtained.

Having a particular radio calibrated in the manner described above, it is a simple matter to chart the harmonics of the testing set.

Once the frequencies of the *modulated radiator* harmonics are known, the testing set may be used instead of broadcasting stations for plotting other dial calibration graphs for other radios, or for checking the accuracy of the calibration of radios the dials of which are already calibrated in kilocycles, wave-lengths, or both.

Final Check Up.—As a final check up on each completed service job, it is recommended that the *modulated radiator* be set up and each of its harmonics tuned in.

The radio man should soon acquaint himself with the relative strength of these signals, and the audible pick up response of the average radio to these signals. Dial calibration, as described above, affords an excellent final check up on the operating characteristics of a radio.

Sources of Radio Trouble.—The following trouble list will afford a quick reference guide for the service man during the process of servicing. The source of the trouble may frequently be found by reference to the list.

When

All tubes fail to light

A battery discharged;

Open rheostat;

Poor battery connection;

Broken lead in battery cable;

Poor switch;
Burned out tubes;
Open primary of power transformer (*a.c.* set);
Open in *a.c.* lead cord;
Fuse blown.

Part of tubes fail to light

Open rheostat;
Dead tube;
Open in power secondary;
Poor socket contact.

No reception (set dead)

B supply dead or defective;
May be B batteries down, open in power secondary, defective rectifier tube, shorted power supply condenser, open choke in power unit, defective resistor in power unit, open in plate cable lead;

A battery connections reversed;
Open primary of radio frequency transformer;
Open primary of audio frequency transformer;
Shorted grid condenser;
Open or shorted speaker cord;
Shorted by pass condenser;
Defective tube;
Open or shorted speaker choke;
Open circuit in wiring;
Short circuit in wiring;
Tube prongs not making contact in socket;
Grid resistors open;
Short between aerial and ground leads;
Shorted lightning arrester.

Weak reception

Defective tube	Partially shorted power transformer secondary
A or B voltages low	Poor rectifier
Corroded battery connections	Poor lightning arrester
Partially shorted audio transformer	Incorrect eliminator resistor values
Partially shorted radio frequency transformer	Poor aerial insulation
Open radio frequency transformer secondary	Poor ground
Leaky audio transformer	Poor socket contacts
Set out of synchronization	Defective grid condenser
Poor grid resistors	High resistance wiring connection
Partially shorted power transformer primary	Speaker weak
	Speaker out of adjustment

Noisy

A.c. plug loose	Loose contacts in socket
Swinging antenna, grounding	Defective filter condensers, punctured
Poor lightning arrester	Defective audio transformer, grounded
Defective ground connection	Defective eliminator resistors
Defective by pass condenser	Grid resistor open
Defective tube	Poor battery connections
Variable condenser shorted	Defective B batteries
Variable condenser dirty	Speaker cord shorted, partially
Defective grid leak	Speaker cord tips loose
Defective resistors	Speaker unit defective
Loose connection in wiring	Dirty switch contacts
	Volume control worn

Distortion

Defective A or B power supply or overloaded	Shorted biasing resistor
Speaker out of adjustment	Poor rectifier tube or elements
Poor tube	High regeneration
Incorrect type of tubes	Reaction between radio and audio frequency elements
Incorrect battery voltages	Inter-action between transformers
C battery disconnected	Acoustic coupling between speaker and set
Incorrect C voltage	Poor by pass condensers
Set out of synchronization	Reactive coupling in power leads
Open biasing resistor	

Hums or continuous whistle

Defective tube	Cooked winding of power transformer
Speaker too close to set	Ground binding posts not making good ground contact
Defective power supply	Grounded choke
Open grid circuit	Grounded speaker jack
Low detector voltage	Grounded resistors
Grounded audio transformer	Open grid circuits
Open antenna choke	Open or shorted or grounded by pass condensers
Partially open power transformer secondary	Open resistor
Open filament balancing resistances	Open leads in cable
Shorted filter choke	Shorts in wiring
Open primary circuit	Reaction between wiring
A.c. plug in wrong position	

Intermittent reception

Poor tube	Defective grid leak
Loose connections	Open in grid circuit resistors
Poor lightning arrester	Corroded connections

Poor aerial insulation	Weak A battery
Poor grounds	Defective rectifier tube or elements
Swinging ground or aerial	Open biasing resistor

Overheating

Shorted power transformer primary Shorted power secondary circuit

Continued oscillation

Defective tube	Open grid circuit
Poor ground connection	Antenna lead too close to set
Grid resistor shorted	Reaction or poor shielding
Excess radio frequency plate voltage	Poor radio frequency by pass condensers

Power Pack Tests—Type Variations.—In making tests on power packs, it should be remembered that there are slight variations in circuital arrangements of power packs, and that the manufacturer's diagrams, if available, should be studied for any device under test.

Most power packs employ tapped voltage divider resistances which carry waste or "bleeder" current for improved voltage regulation, while with some there is no continuity from the positive to the negative side of the filter through the divider network.

In the latter types, the whole output of the filter system generally passes through a series of plate circuit resistances, and through the tubes and biasing resistors employed in the radio, detector, and audio systems.

Power Pack Troubles.—Any defect in a power pack will generally be reflected in the plate voltage and current readings obtained by analysis of the tube sockets of the radio supplied by the power pack, and such an analysis should precede any *power plant* tests.

It follows that normal load voltages applied to the various tube sockets of the radio should generally indicate normal power pack conditions. There are possible exceptions, however, as in the case where a few shorted windings in the power transformer may cause excessive heating of the transformer without negligible variations in the output voltages of well regulated power packs.

Transformer Defects.—The operation of the modern type of radio is usually controlled by an *on off* switch which opens or closes the power transformer primary. Obviously, an open primary circuit of a power transformer would result in no voltages in the secondary circuits of the power transformer.

Shorted turns in any of the transformer windings would cause excessive heating of the transformer, with lowered voltages across the secondary circuit in which windings are shorted. In the case of the center tapped full wave rectifier plate secondary, shorted windings on either side of the center tap will result in an unbalanced condition, the voltage applied to one plate being lower than that applied to the other plate. An open in the center tap lead would result in no voltages applied to the filter system.

Filter Defects.—Some radios employing dynamic speakers utilize the field windings of the speaker as a part or all of the choke in the filter circuits of the power pack. An open choke will result in no output voltages.

A similar result will be obtained when the other side of the filter is open. Shorted windings within the choke may cause excessive output voltages with hum. Filter condenser leakages reduce the output voltages, a shorted condenser across the filter system resulting in no output voltages, and an analysis from the rectifier tube socket would reveal excessive rectifier plate current.

An open filter condenser would probably introduce hum in the loud speaker output.

Some power packs include by pass condensers between the grounded or negative side of the filter and each plate voltage tap. A leaky or shorted by pass condenser would reduce the voltage available between the corresponding tap and the common negative side of the filter and voltage divider system.

Voltage Divider Defects.—Some power packs are designed so that the *bleeder* or waste current through the voltage divider exceeds the load current of the radio to be supplied with the power pack. The most common voltage divider defects are open circuits.

An open divider results in no plate voltages on tubes supplied with a lower or intermediate plate voltage, with excessive plate voltage on the power or other tubes supplied with the higher plate voltages. A shorted plate circuit by pass condenser would result in a shorted section of the voltage divider system.

Grid Biases.—In some radios, the grid biasing resistors are included in the power pack. An open grid bias resistor has the effect of opening the plate circuit of the tubes biased with the resistor. A short circuited or leaking by pass condenser loses its by passing qualities, and if connected across a biasing resistor, the effective resistance of the bias is lowered, resulting in excessive plate current in the tubes depending on the resistor for grid bias.

Diagnometer Tests.—The plate current of rectifier tubes may be measured in the same manner as employed for other tubes. However, when analyzing from thermionic full wave rectifier tube sockets, the current of only one plate can be determined.

With a normal tube and properly functioning power pack, the total rectifier plate current would be double the value obtained. The 750 volt scale of the *a.c.* volt meter is helpful in making tests of the *a.c.* voltages applied to rectifier plates, and for determining unbalanced plate secondaries. Such tests should be made from plate to plate in full wave rectifier sockets, and from each plate to the rectifier filament, the chassis, or radio cathode circuits. The *a.c.* plate voltages should be the same for each plate of full wave rectifier tube sockets, and each voltage should be about half that indicated from plate to plate.

The high voltages encountered in power packs necessitates caution in such tests so as to prevent bodily harm. In any test the isolation of defects is facilitated if the manufacturer's service data be available.

TEST QUESTIONS

1. *What kind of an outfit should a service man be provided with to properly test radio sets?*
2. *What is the first step in servicing?*
3. *What equipment is used with testing sets?*
4. *Describe the method of putting the testing set with its various attachments into operation.*
5. *Describe methods used in testing tubes.*
6. *How are tube socket circuits tested?*
7. *Explain the method of screen grid tube socket analysis.*
8. *What is the object of making no load and load voltage tests?*
9. *Describe filament circuit analysis.*
10. *What does failure to obtain any filament reading indicate?*
11. *How are plate voltage readings taken?*
12. *Explain fully the method of plate circuit analysis.*
13. *Explain grid circuit analysis.*
14. *How is the correct voltage reading on the bias obtained in radios employing biasing resistors?*
15. *What kind of voltage reading is obtained when analyzing from the detector socket and why?*

16. *Describe the cathode circuit analysis.*
17. *How is a defective cathode bias indicated?*
18. *Explain the method of screen grid analysis.*
19. *How is overhead heater filament analysis made?*
20. *Describe distortion test.*
21. *How should lightning arresters be checked?*
22. *How should the output circuit be tested?*
23. *Describe synchronizing procedure.*
24. *Describe neutralizing procedure.*
25. *How is a dial calibration chart made?*
26. *Name the multiplicity of sources of radio trouble.*

CHAPTER 184

Radio Compass

The radio compass, invented by F. S. Kolster, is a device with which bearings can be taken in dense fog, snow storms and over distances greatly beyond the horizon with an accuracy equal to that obtained with visible sights, thus eliminating one of the greatest hazards to navigation.

Although light vessels and light houses are maintained along the coast and harbor entrances the world over, they fail to serve their purpose adequately during fog or thick weather.

Light waves do not penetrate fog to any practical distance and sound waves, due to echo effects, are unreliable and cannot be depended upon to indicate either direction or distance. On the other hand electro-magnetic or so-called radio waves, do penetrate fog and can be used through the medium of the radio compass to indicate both direction and distance.

The modern method of obtaining radio compass bearings on shipboard requires the installation of radio beacons on light vessels and light houses in the vicinity of harbor entrances and other places dangerous to navigation, the exact locations of which are clearly shown on all sailing charts.

The radio beacon sends out characteristic radio signals by which the operator of the radio compass may take bearings. Such beacons are under the supervision of the U. S. Bureau of Lighthouses, the sole purpose of which is to maintain aids to navigation.

The navigator of a vessel equipped with a radio compass can take bearings as often as is desired without requesting the cooperation of anyone and without the knowledge of any second party either on board ship or on shore.

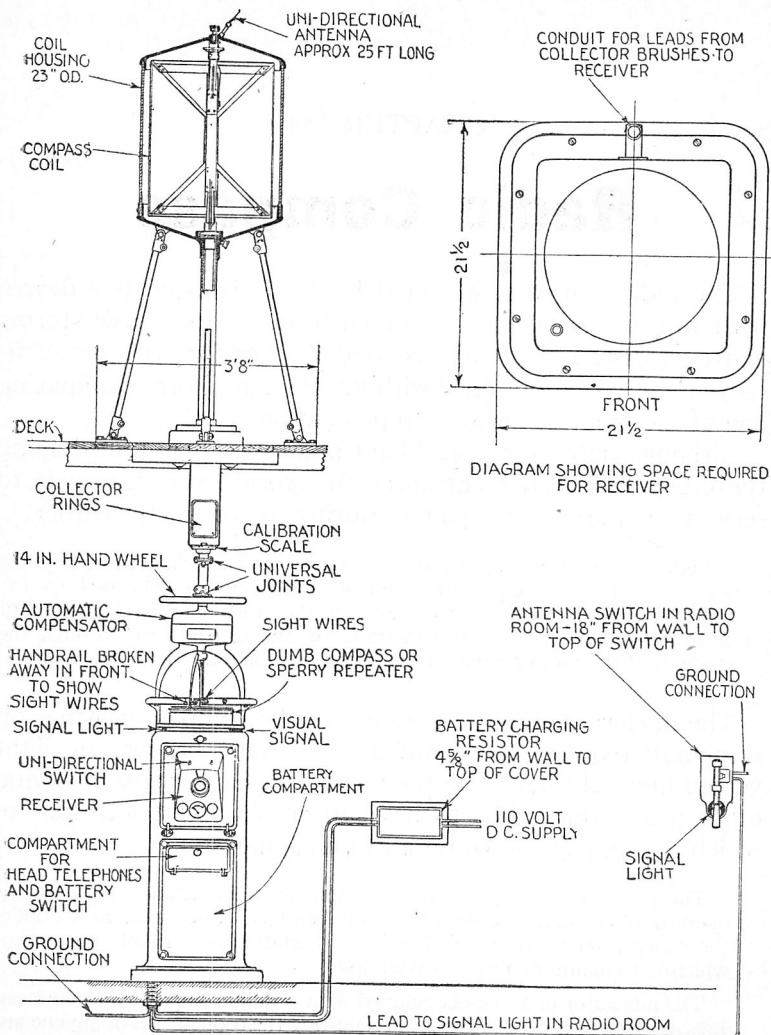


FIG. 7,409 and 7,410.—Kolster radio compass installation.

Since each vessel is equipped with its own radio compass any number of vessels can take simultaneous bearings.

The compass is direct reading thus eliminating the possibility of error in applying correction.

It is possible for vessels equipped with radio compasses and radio transmitters to safely pass in fog by taking bearings on each other.

A vessel equipped with a radio compass may obtain a leading bearing to another vessel calling for assistance and thereby proceed immediately and directly to the scene of the disaster in either fog or clear weather.

A typical radio compass installation is shown in figs. 7,409 and 7,410.

Radio Compass Construction.—A suitable loop frame is wound with several turns of special radio frequency cable to form a coil. The frame is mounted edgewise upon a vertical hollow shaft which is in turn supported by a ball thrust bearing for ease in turning.

The coil is enclosed within a circular housing in a manner such that it is free to rotate even under the most severe conditions of the wind and sea. This is of value in northern latitudes, where, during the winter months, the ship's superstructure is generally covered with ice. The housing also protects the coil from mechanical damage.

The coil and housing with its stem are mounted on the upper deck, the base of the loop housing projecting approximately six inches above the surrounding hand rail. The assembly is rigidly supported by four braces which may be supplied in various lengths to suit the installation.

The shaft on which the coil is supported extends through a suitable housing to the room in which the compass is located. The leads from the coil pass through the tubular shaft to a set of collector rings. From the collector rings the leads pass through a conduit to the compass receiver which is located in the upper part of the compass binnacle.

At the lower end of the shaft there is attached a pair of sight wires which travel over a compass card or azimuth circle by means of which the angle between the station upon which the bearing is taken and magnetic North, true North, or the ship's direction (depending on the type of installation) can be read directly.

The sight wires are not rigidly fastened to the shaft but are connected thereto through a simple mechanical device which automatically corrects for variations in the direction of the incoming radio waves caused by the influence of the ship's hull and rigging. This device is called the Automatic Compensator.

Operation.—When the coil is rotated by means of a hand wheel, the characteristic signal from the beacon station will be heard in the telephones with a gradual varying degree of loudness until the plane of the coil is at right angles to the direction of the incoming waves, at which point the signal fades out entirely.

This position of silence is very critical and sharp and therefore indicates with great accuracy the line of direction of the waves. By means of cross bearings on two or more stations or by several bearings on a single station with the distances logged between bearings, the position of the ship can be determined by simple triangulation with an accuracy equal to sight bearings on visible fixed objects.

In obtaining a compass bearing it is essential to eliminate the so called antenna effect of the compass coil. This is accomplished by a simple adjustment on the receiver panel.

Although two bearings 180 degrees apart can be obtained, they do not indicate more than the waves' line of travel and before accurate bearings may be taken it will be required to know the true direction from which the waves are approaching.

To obtain the true direction it is necessary to *unbalance the compass coil by exaggerating the antenna effect.*

This is done by connecting a small antenna, usually not greater than twenty-five feet long, to the receiver through a suitable spring switch, also located on the receiver panel. Normally this uni-directional switch remains open when taking a bearing but when the true direction is desired the operator closes the switch by a slight pressure of the finger and turns the compass coil to the position of maximum signal strength, at which point the

plane of the loop lies in the direction of the signaling station and points toward it as indicated by an index pointer provided for the purpose.

In the construction of the compass one end of the sight wire frame is painted white, further identified by a recessed star, painted grey and referred to as the *star end*. This end should always be turned toward the beacon on which bearings are to be taken.

Visual Indicator.—The method of obtaining a bearing by means of visual indicator consists *in observing the change in brilliancy in the glow of a gaseous conductor lamp*.

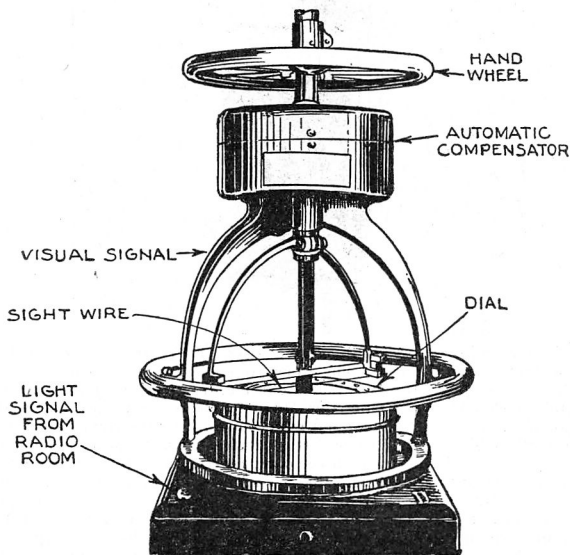


FIG. 7,411.—Kolster dumb compass and compensator.

It will be found that the lamp will cease to glow between two readings of the sight wires, the mean of which will be the true bearing. The width of the compass sector over which the sector is dark will depend on the strength of the transmitting station and the distance from the station to the ship taking the bearing. A reading accurate to within two degrees can usually be obtained over a distance of 25 miles.

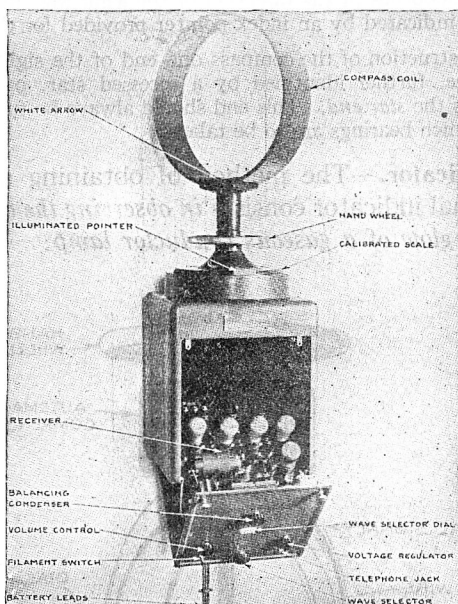


FIG. 7,412.—Kolster radio compass with receiver open. *In construction* a suitable coil is formed by winding several turns of a single piece of special high frequency cable in grooves on the periphery of a cylindrical shaped bakelite frame, the ends terminating at a receiver, by means of suitable collector rings, located directly under the coil pedestal. The shaft on which the coil is mounted, is connected to a hand wheel for rotating the compass coil while taking bearings. Directly under the hand wheel is a short pedestal to which a flat circular 360° scale is secured. This scale rotates with the compass coil under a fixed pointer in the form of a glass window with an engraved sight line. The glass window is provided with a low candle power lamp for illuminating the scale under the sight line for use at night. Bearings are read directly from this scale. The zero degree mark must be kept turned toward the beacon on which bearings are taken. For convenience, so as to facilitate locating its position without reference to the engraved figures on the scale, the zero side of the coil is identified by a large white arrow painted on the upper casting of the coil support. *In operation*, as the coil is rotated, the characteristic signal from the beacon station will be heard in the telephones with a gradual varying degree of loudness, until the plane of the coil is at right angles to the direction of the incoming wave, at which point the signal fades out entirely. This position of silence is very critical and sharp and, therefore, indicates with great accuracy the line of direction of the wireless waves. The bearing is then read directly from the calibrated scale on the degree mark which registers with the sight line engraved on the glass window. The manner of taking bearings with this type of radio compass is precisely the same as obtaining sights with the pelorus on visible fixed objects. In both cases the bearings obtained are with respect to the ship's head. By reference to the vessel's magnetic or gyro-compass, as the case may be, the position may be plotted by simple triangulation.

The visual indicator possesses several advantages not possible with the audible system of taking bearings.

As an example; it is possible to orientate the radio compass coil such that a signal transmitted from either a land beacon or a mobile radio beacon installed on another ship will cause the lamp to light up as soon as the vessel comes into a dangerous position. By this means the navigator on the bridge does not have to keep continuous watch on the radio compass but may walk around the bridge, occasionally glancing at the lamp which is always visible when glowing. As soon as the navigator is aware of approaching danger, he can then take a compass bearing, determine the exact position of his ship and act accordingly.

Receiver.—The radio compass receiver is located directly beneath the compass as shown in fig. 7,412 and utilizes *a circuit specially designed to give maximum sensitivity and selectivity.*

The receiver contains seven tubes, large type, so operated that they are equivalent to four stages of radio frequency amplification, a detector and two stages of special design audio frequency amplification. The receiver is designed to operate over a wave length range of from approximately 550 to 1,050 meters.

Tuning is accomplished by a one dial wave selector. The dial having an engraved scale in degrees and lettered to designate the position of three major wave length zones, namely, Radio Beacon (1,000 meters), Navy Compass Stations (800 meters) and Ship Stations (600 meters).

A low candle power lamp is located in the receiver cabinet directly behind the above scale which serves the purpose of indirect lighting, giving a subdued illumination of the dial for night use. The azimuth circle and dumb compass, when supplied is similarly illuminated. The Kolster radio compass can be operated as satisfactorily in a darkened chart or wheel house as during the day.

Should the receiver in the radio room become irreparably damaged, communication could be carried on by using the compass receiver. Its normal receiving range is 250 miles for day and 1,500 miles at night.

The A and B batteries for the tube filaments and plates respectively are located beneath the receiver at the bottom of the binnacle. The A battery consists of an Edison storage battery which is designed for reliability and long service. A double pole double throw snap switch is located within the telephone compartment directly beneath the receiver by means of which the battery may be connected either to the receiver or to the ship's mains for charging. A charging resistor to limit the amount of current is mounted in some suitable location in series with the ship's supply.

The battery when kept fully charged, has a useful life of approximately eighteen hours continuous service. This reserve is valuable in case the vessel become totally disabled, as the compass could still be operated for a period governed only by the condition of its battery.

The antenna switch and signal light shown in fig. 7,409 are for the purpose of assuring that the ship's main antenna switch is open when bearings are taken.

This antenna switch is normally located in the ship's radio room under control of the radio operator. Red lights on the base of the switch and on the radio compass binnacle indicate that the antenna switch is open. If the light on the binnacle is not lit when it is desired to operate the compass, the navigator communicates with the radio personnel and requests that the antenna switch be opened before taking bearings.

TEST QUESTIONS

1. *Who invented the radio compass?*
2. *How does a radio compass work?*
3. *Is a radio compass direct reading?*
4. *Describe the construction of a radio compass.*
5. *Explain in full detail the operation of a radio compass.*
6. *What is the visual indicator?*
7. *Explain the method of obtaining a bearing by means of the visual indicator.*
8. *Describe the construction of the radio compass receiver.*
9. *How is tuning accomplished?*

CHAPTER 185

The Telephone

By definition the telephone is *an instrument for the transmission of articulate speech by electric current.*

Principle of the Telephone.—The operation of the telephone is based upon a simple principle, namely, *using a continuous*

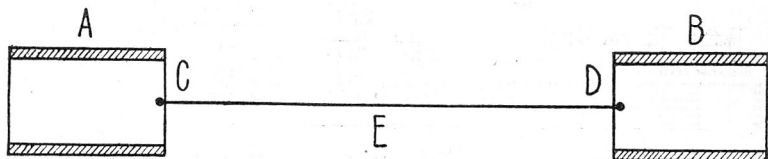
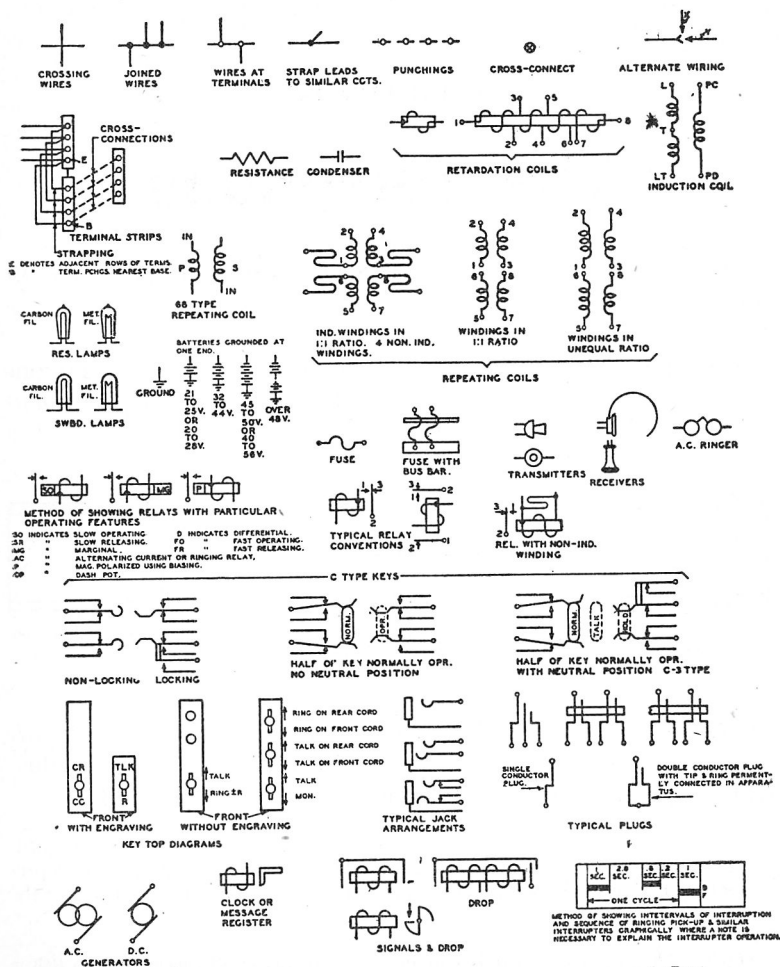


FIG. 7,413.—Diagram of simple toy telephone, consisting of two combined transmitters and receivers A and B, made of metal or wood cylinders, one end of each being covered by a membrane C and D, and the centers of which are connected by string E.

current of electricity and varying its strength exactly as the air varies in density during the production of sound. This is illustrated by the simple toy telephone shown in fig. 7,413.

In operation, when the open end of the tube A, is placed before the mouth, the vibrations of the membrane C, caused by the varying sound waves representing the human speech, are transmitted with mechanical action by the

NOTE.—*The principle of the telephone* was discovered by Alexander Graham Bell in Boston, Mass., on June 2nd, 1875. The first telephone was actually operated on March 10, 1876; it was then a crude instrument and not very sensitive. Since that date however many improvements have been made in this agency of communication that has made America a neighborhood.



FIGS. 7,414 TO 7,477.—Symbols used in manual telephony.

string E, to the membrane D, and set up in the latter vibrations corresponding to those of C. The vibrations of D, cause sound waves in the air which are transmitted to the ear placed at the open end of the cylinder B.

The Transmitter.—In the electric telephone, the string is replaced by a wire having at one end a small unit consisting of

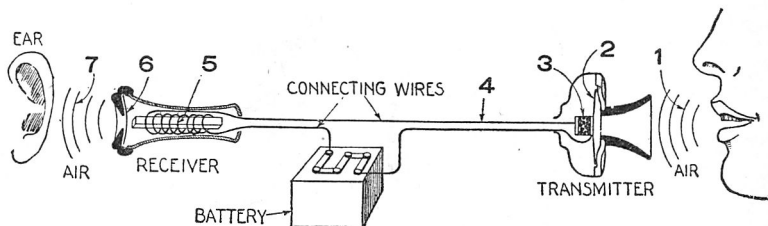


FIG. 7,478.—Electric telephone. *The parts are:* 1, air vibrations caused by voice; 2, diaphragm; 3, carbon buttons; 4, line wires; 5, electro-magnet; 6, diaphragm; 7, reproduced air vibrations representing speech.

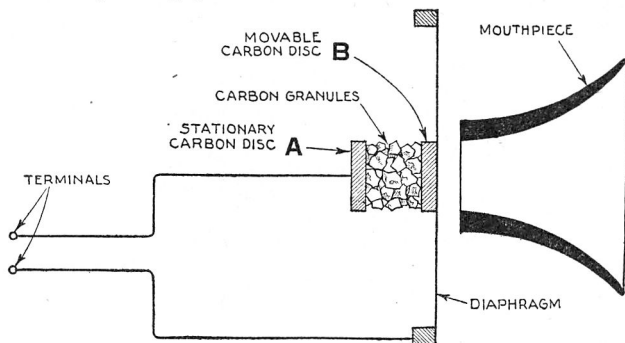


FIG. 7,479.—Simple electric telephone transmitter.

two carbon discs separated by about $\frac{3}{32}$ of an inch and the space between filled with sharp carbon particles called granules, as shown in fig. 7,479. This unit is connected to a steady source of electricity so that the current must flow from one carbon disc through the carbon granules and out through the second carbon disc.

The arrangement normally offers a certain amount of resistance to the passage of the electric current. However, if the space between the carbon discs be decreased the carbon granules become packed closer together, lessening the resistance and allowing a greater amount of electricity to flow through. Vice versa, if the space between the granules be increased, the result will be an increase in resistance and a decrease in the electric current.

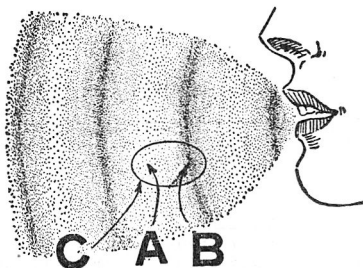


FIG. 7,480.—Microscopic view showing molecules of air at 1, in fig. 7,478. In a spoken word, or in any musical sound, the molecules dance back and forth as in fig. 7,481.

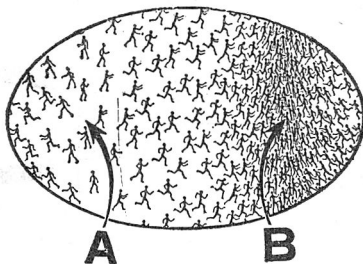


FIG. 7,481.—Enlargement of section C of fig. 7,480 with molecules represented as tiny beings rushing from A to B (fig. 7,480). First they advance, pushing against the ear drum, and then they retire and the membrane of the ear flies back. Over and over again this happens, hundreds and even thousands of times a second. The higher pitched the voice of the speaker, the more rapid is the dance, yet it is a dainty dance, for the weight of a snip of human hair only about one-thousandth of an inch in length would press as heavily upon the sensitive ear drum.

One of the carbon discs A, is held in a fixed position and the other B, is attached to the center of an aluminum disc called a *diaphragm*. The entire arrangement is called a *transmitter*. In operation the voice sets the air into vibrations which beat upon the transmitter diaphragm and set it into rapid

back and forth movements, causing changes in the resistance of the carbon unit and resulting in the rapid variations of electric current which flows to the distant end where there is a receiver, as shown in fig. 7,478.

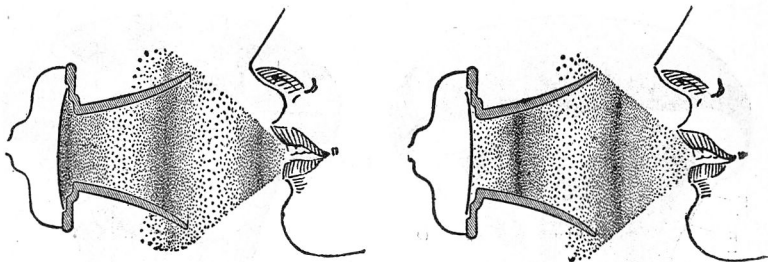
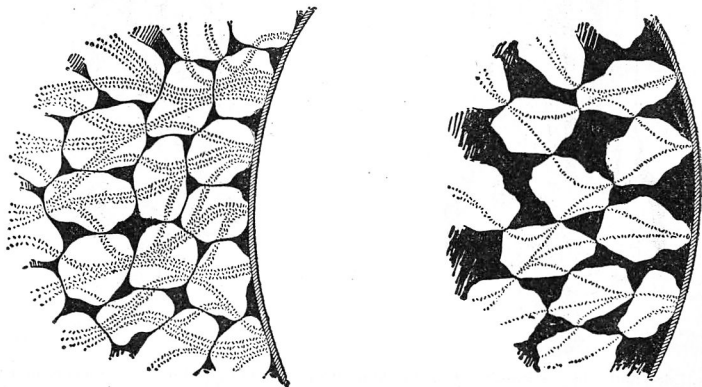


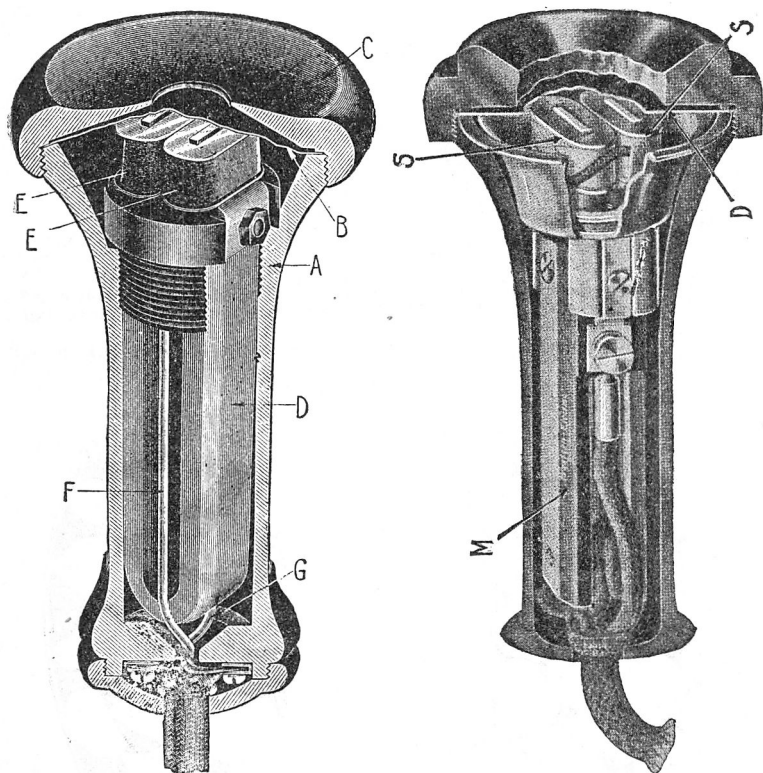
FIG. 7,482.—Effect on diaphragm caused by molecules of air which are set in motion by the voice of the speaker—they rush against the diaphragm of the transmitter and bend it in.

FIG. 7,483.—Effect on diaphragm when the molecules rush away—it springs back out of its bent position.

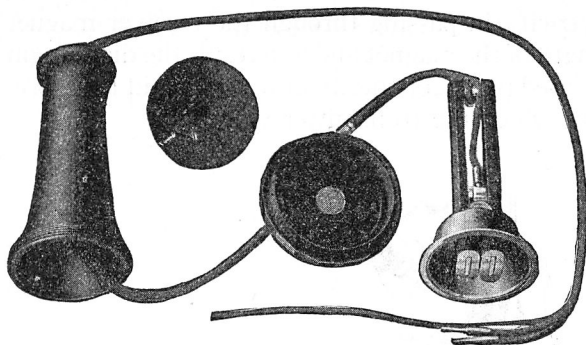


FIGS. 7,484 and 7,485.—Action of diaphragm on carbon grains. Fig. 7,484 shows carbon grains in a transmitter magnified about fifty times each way. When the diaphragm is bent in, the grains are closely packed together and many electrons can pass through, but when the diaphragm springs back, as in fig. 7,485, the grains are loosely packed and fewer electrons can pass from grain to grain through the chamber containing the carbon grains.

The Receiver.—This consists of an electro-magnet with an iron disc or diaphragm, very near its poles. The varying

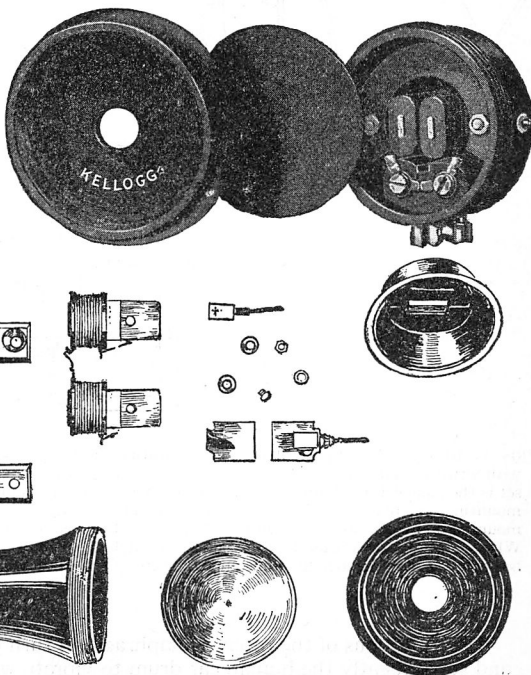


FIGS. 7,486 and 7,487.—Standard bi-polar hand receiver. The winding of the coils is done with silk covered copper magnet wire. The outside terminals are soldered to metal strips which are insulated and extend to the cord terminals within the shell. The magnet is a single piece, being formed from a bar of magnet steel. It slips into the casing which forms a support for all the parts and is held by a screw cap. All parts are thus firmly clamped together, but the screw cap plays no part in the adjustment. The metal strips terminate in a brass support to which are fastened the receiver cord terminals.



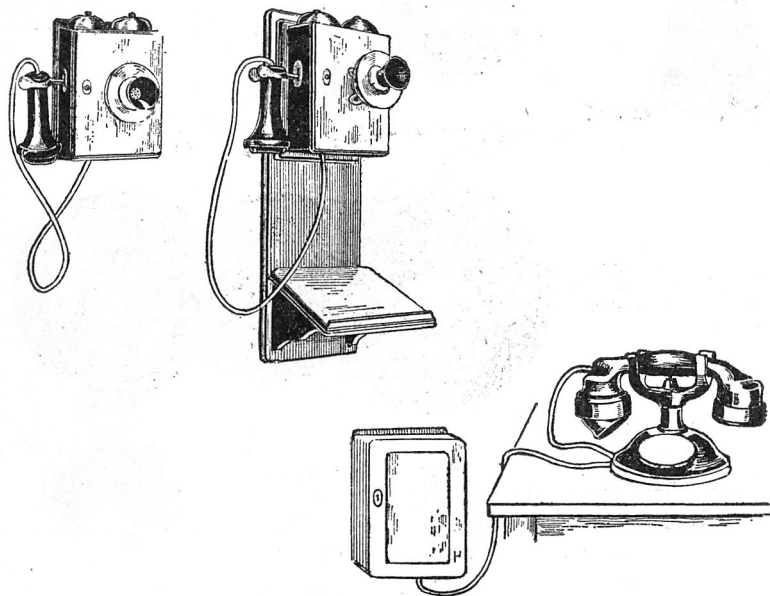
FIGS. 7,488 and 7,489.—Kellogg subscriber's receiver, disassembled showing construction.

FIG. 7,490.—Kellogg operator's receiver, disassembled showing diaphragm and magnet.



FIGS. 7,491 to 7,509.—Parts of Kellogg shell receiver.

amounts of electricity in passing through the receiver magnet change the strength of the magnet and as a result the diaphragm is pulled and released partly or totally at a very rapid rate, precisely the rate at which the transmitter vibrates.



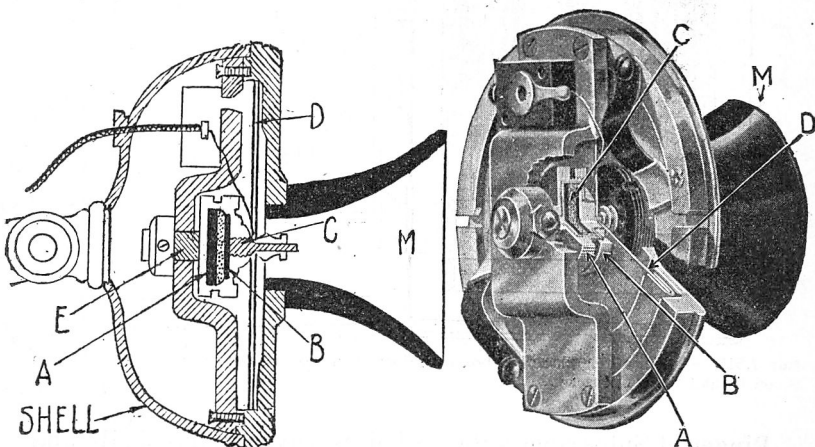
FIGS. 7,510 to 7,512.—Types of station apparatus. Fig. 7,510, wall set; fig. 7,511, wall set with writing shelf; fig. 7,512, desk stand or hand set with a separate bell box. The wall set is the smallest and lightest of these three types of instrument and is generally used where mountings on plaster walls are required. Where a writing shelf is desired the wall set is mounted on a back board equipped with a shelf. It is fastened to the wall with anchor bolts. Where a table or desk is used by the subscriber, a desk stand or hand set is installed, the bell box being mounted under the table and connected to the desk stand by a flexible wire cord.

The vibrations of the receiver diaphragm in turn cause the air to vibrate and subsequently the human ear drum to vibrate when the latter is placed close to the receiver. The result of course is the reproduction of speech.

Ques. Of what does a telephone station consist?

Ans. It consists of a transmitter and a receiver usually on a desk stand with a hook to hold the receiver, and also to serve as an automatic switch when the receiver is removed from the hook, as in fig. 7,523, connected to a bell box which contains
1. A condenser. 2. A bell, and 3. An induction coil.

The electric current necessary for talking purposes is obtained from a storage battery located at a central point known as the "common battery central office" and the alternating current to ring the bell is furnished by a ringing machine, also located in the Central Office. This is known as the common battery system.



FIGS. 7,513 and 7,514.—Commercial transmitter. *The parts are:* A, fixed carbon disc attached to the bridge at E; B, movable carbon disc attached to the center of the aluminum diaphragm D, at C; M, hard rubber mouth piece. The shell is for protection and for mounting the transmitter to a stand or bracket.

A commercial transmitter is shown in figs. 7,513 and 7,514, and a typical receiver in fig. 7,487. The receiver generally consists of a small U magnet M, made of a very good grade of steel with many turns of fine insulated wire S S, wound around its two poles, and an iron diaphragm D, located very near the poles, but not in contact with them.

Subscriber's Set.—In the bell box, known as the subscriber's set, shown in fig. 7,515 are three pieces of equipment:

1. Ringer.
2. Induction coil.
3. Condenser.

These are designated A, B, and C, respectively, in fig. 7,515.

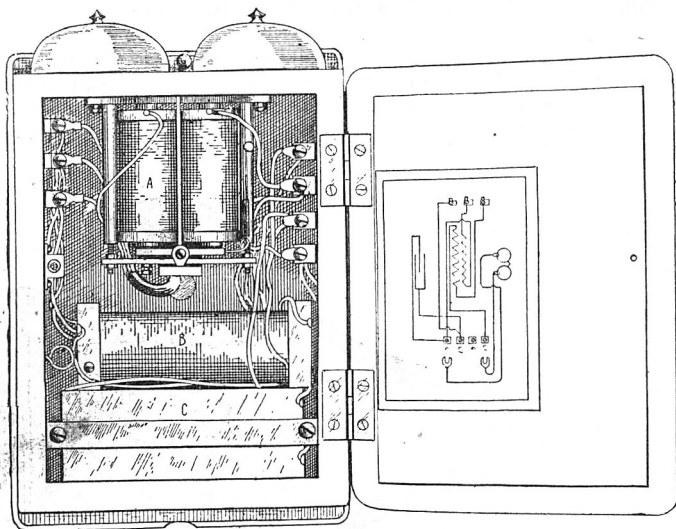
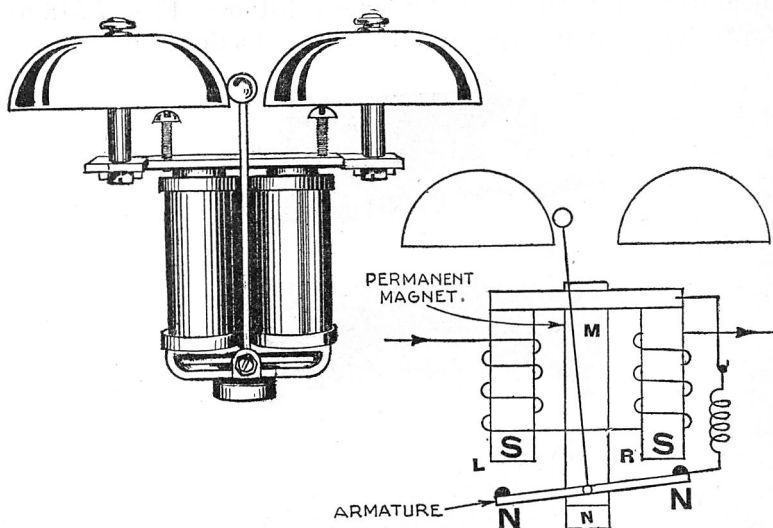


FIG. 7,515.—A typical telephone bell box with door open showing the ringer A, the induction coil B, and the condenser C.

Ringer of Subscriber's Set.—This is shown in figs. 7,516 and 7,517, and is a combination of a permanent magnet M, N, and an electro-magnet L and R, which is an inverted U magnet with many turns of fine insulated wire on each of the soft iron cores L and R, equal turns on each. The permanent magnet M, N, is attached at M, to the center of the electro-magnet. This establishes two south poles S, S, of equal strength, and by induction two north poles N, N, also of equal strength at the

ends of a piece of soft iron pivoted near the poles of the electro-magnet. This piece of soft iron acts as the armature and carries the hammer which strikes the bells.

A biasing spring is attached to the armature at one end, which forces the armature to assume the normal position shown in the figure. If the biasing spring were not there, the armature would just float.

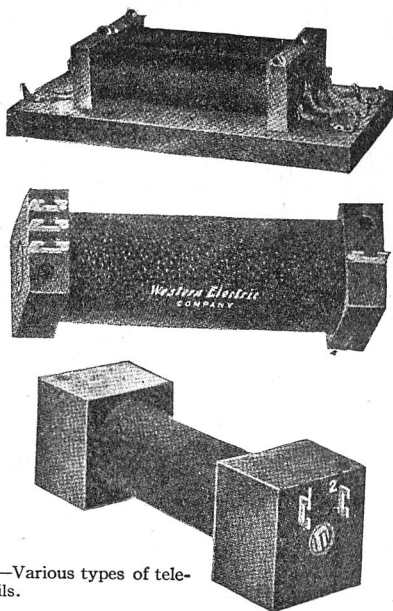


FIGS. 7,516 and 7,517.—Ringer and diagram of its operation.

The ringing current is alternating and reverses itself completely sixteen times in each second. Consequently at some instant the current may be flowing from L, to R, causing the **S** pole at L, to become stronger and the **S** pole at R, to become weaker, and as a result, the armature is pulled toward the **S** pole at L.

When in the next instant the ringing current reverses, the opposite action takes place with the addition of returning power from the biasing spring, so that the armature moves with the reversals of the ringing current sixteen times in one second. The hammer, being attached to the armature, will follow the movements and strike the bells.

Induction Coil of Subscriber's Set.—This consists of two windings on a soft iron core made up of a bundle of soft iron wires or laminations. The primary is wound over the iron core and the secondary over the primary. The induction coil is connected so that it is between the transmitter and the distant receiver in order to amplify the talking currents and enable them to reach a comparatively longer distance. Figs. 7,518 to 7,520 show various types of telephone induction coils.



FIGS. 7,518 TO 7,520.—Various types of telephone induction coils.

Condenser of Subscriber's Set.—The condenser consists of two sheets of tin foil separated by a double thickness of paraffined tissue paper. The tin foil sheets are approximately $3\frac{1}{2}$ ins. wide and are very long, so as to give the effect of a large surface.

The paraffined paper is slightly larger in width and is interposed between the two sheets of tin foil to prevent their coming in metallic contact. The combination is rolled up so as to occupy a small space, and is then boiled in paraffin and encased in a metal container for protection. A lug is attached to each sheet of tin foil so that wires may be soldered to it.

Fig. 7,521 shows a typical telephone condenser.

In operation, a condenser acts as an insulator in a telephone circuit where direct current is applied, but it readily allows the passage of alternating current. It is used in the subscriber's set connected in series with the bell so as to prevent the storage battery current passing through the bell from one side of the line to the other causing unnecessary waste of electricity.

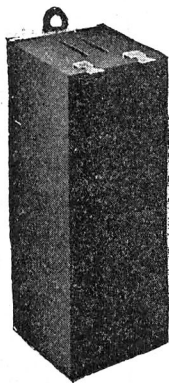


FIG. 7,521.—Typical telephone condenser.

Station Line Circuit.—The connections of the apparatus in the bell box and the receiver and transmitter, are shown in fig. 7,522. On a call originating at this station the telephone user lifts the receiver off the hook.

This completes the path of the electric current from one side of the line at A, through the primary of the induction coil and transmitter to the other side of the line at C, and causes a relay in the subscriber's line circuit in the Central Office to operate and a lamp to light on the switchboard in front of an operator to notify her that a connection is desired.

On a call coming into this station line circuit a connection is made in the Central Office which places generator current (16 cycles *a.c.*) on the line and rings the bell shown in fig. 7,522.

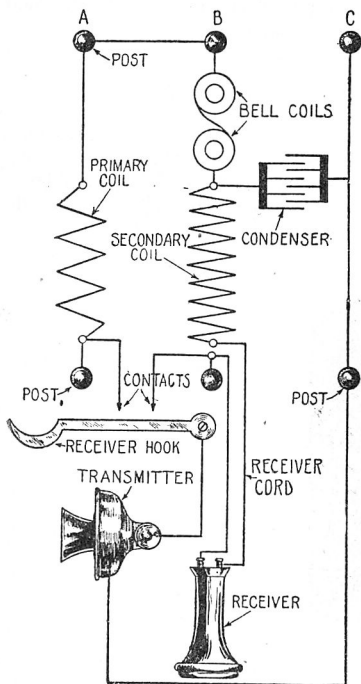


FIG. 7,522.—Diagram showing the inside connections of a telephone bell box, the binding posts of which are shown, top and bottom. Flexible wire cords connect these to the transmitter and receiver, as shown. When the receiver is off the hook the contacts there are closed by the upward spring of the hook and the circuits are closed for operation. The line is always connected to the two outer posts A and C, the middle post B often stamped G and used for ground connection on party line instruments. Terminals A and C, are generally designated T and R (tip and ring).

Desk Stand Telephone.—

This piece of apparatus is shown unassembled in fig. 7,523. The connections in the stand are in general, as shown in fig. 7,524.

Coin Box Telephones.—

This type of telephone is shown in fig. 7,525, and consists of the usual transmitter and receiver, and a bell box containing an induction coil, a condenser, and a bell. In addition there is a *coin collect and return magnet*.

The coin machine consists of an upper housing encasing a chute with entrance points at the top for 5c, 10c and 25c coins. The lower portion of the chute opens into a hopper. The coin when dropped into the chute follows a zig-zag path and finally drops onto a small platform or *coin trap*. However, before reaching this point, the coin has accomplished two things: 1, struck a gong; and 2, tripped a small lever which causes a set of contact springs to come together. This in turn causes a lamp to light at the Central Office switch-board giving notice to the operator that a connection is desired.

A 5c piece when dropped into the chute strikes a solid gong once, a 10c piece strikes the same gong twice and a 25c piece strikes a gong of the cathedral type once. The resultant characteristic tones are transmitted to the operator in the Central Office over the telephone wires.

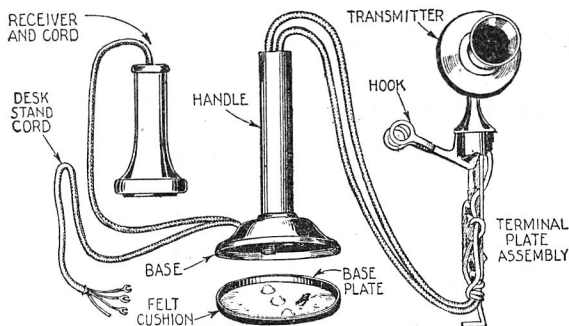


FIG. 7,523.—Desk stand parts.

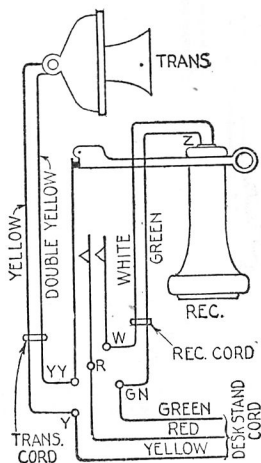


FIG. 7,524.—Wiring of desk stand.

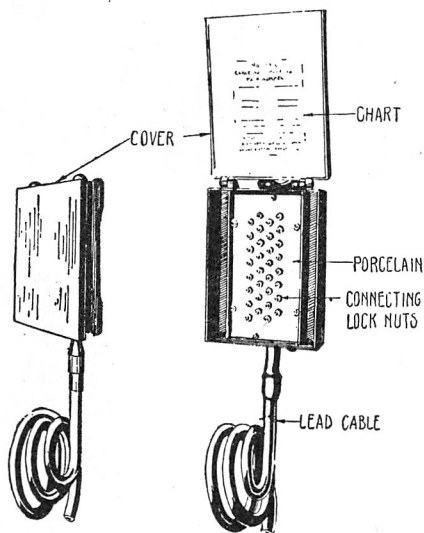


FIG. 7,525.—Coin box telephone.

The operator in the Central Office can either collect or return the coin by operating a *collect* or *return* key.

If the collect key be operated, a magnet in the coin box telephone causes its armature to swing in such a direction as to tip the coin platform toward the coin compartment on account of the weight of the coin, with the result that the coin slides off the platform into a safe.

If the return key be operated, the same magnet operates the armature in the opposite direction, causing the coin to slide off the platform down into the coin return chute. The magnet of this coin box telephone is operated in the same manner as the bell ringer of fig. 7,517.



FIGS. 7,526 and 7,527.—Outdoor cable connecting box. This device is placed in a back yard in cities, or on a pole in the country, and accommodates the two line wires for each telephone in a block or street.

The operation of the collect key sends electric current through the electromagnet of the coin box in one direction, and the operation of the return key reverses the direction of the current flow.

The Common Battery Central Office.—The subscriber station equipment of fig. 7,522 is connected by means of two

twisted insulated wires to a cable terminal located either in the basement of the same building or sometimes outside on a pole or side of the building. This cable terminal, as shown in figs. 7,526 and 7,527, has facilities for connecting a number of telephones.

The wiring from the cable terminal is extended by means of a large lead-covered cable run, either through underground ducts or overhead on poles, to the Central Office:

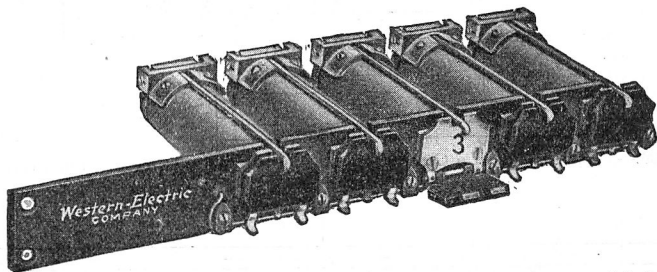


FIG. 7,528.—Mounted trunk drops. Tubular trunk drops are mounted on a metal strip each being held by two small screws underneath the drop shutter. The tubular casing of each drop is soft iron inside of which is the drop winding; the ends of the coil wires terminating at lugs which protrude from the casing and are insulated therefrom. The drop shutters are then screwed fast to the metal strip and adjusted so that they may fall easily when the armature is held up by the magnet.

Ques. What is a Central Office or Telephone Exchange?

Ans. It is a telephone building which contains terminal facilities and equipment to supply the telephone needs of a given district and contains also a switchboard operated by girl attendants who make connections between the telephone subscribers in the same district or with subscribers in another telephone district, or *exchange* by using *trunks*.

Ques. What is the capacity of a Central Office?

Ans. A Central Office may be designed with facilities to handle as many as 10,000 subscribers.

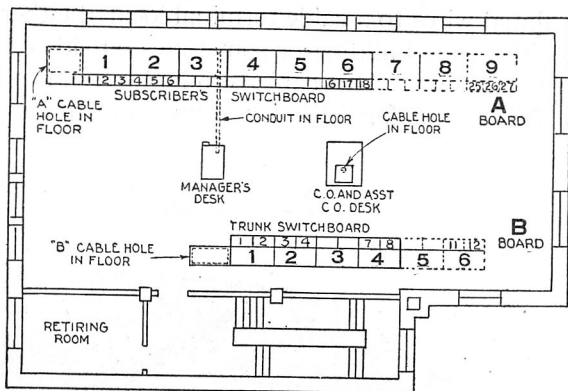


FIG. 7,529.—Typical layout of a Central Office operating room showing the A and B boards.

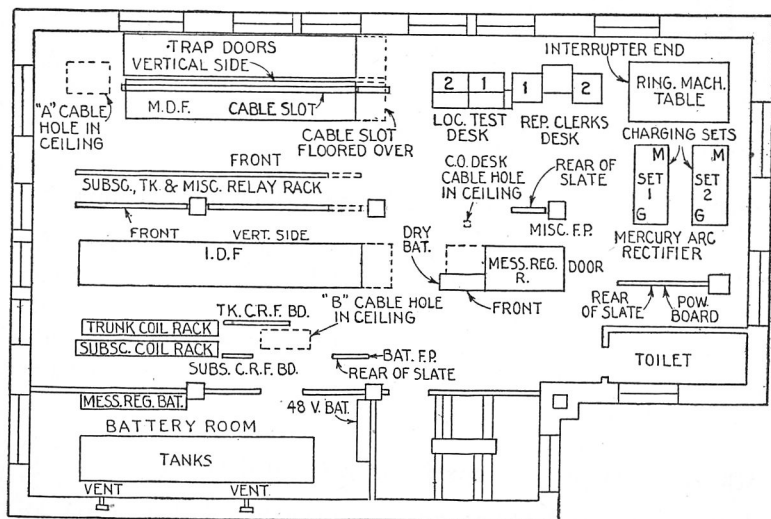


FIG. 7,530.—Typical layout of a Central office terminal room which also contains the power plant equipment.

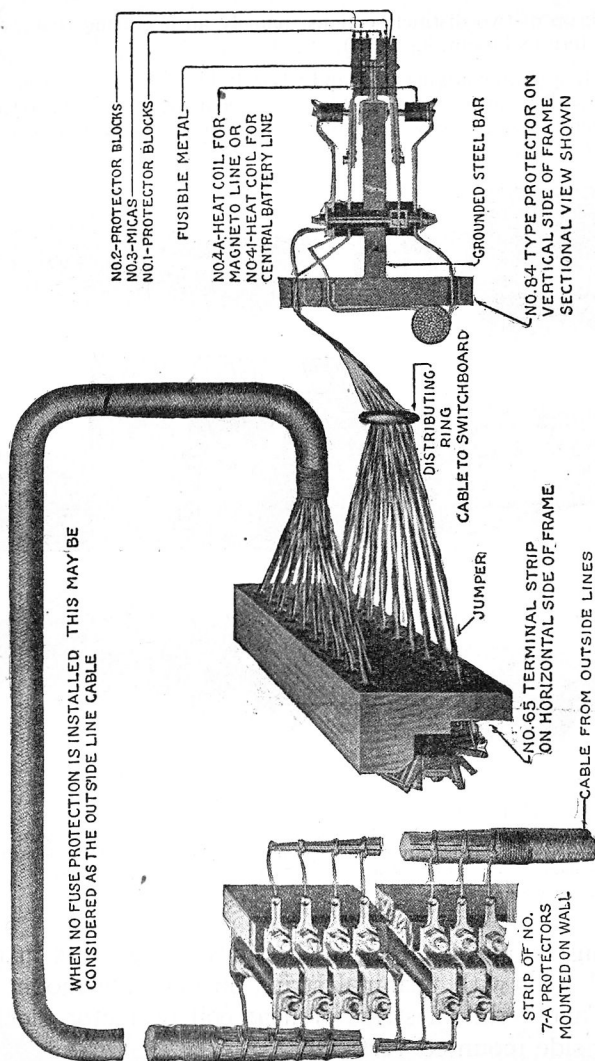


FIG. 7.531.—Typical main distributing frame and connections. All cable wires and jumper wires are in twisted pairs. The terminal strips are mounted on self supporting floor type steel frames. The heat coils, as shown in fig. 7.532, are constructed so that when heavy currents are picked up by the line wires, as in the case of lightning striking the line or crossing with power lines, the heavy current heats a small coil of resistance wire (in the heat coil) which causes a fusible metal to melt and allow a small tube to slide over a pin a distance of $\frac{1}{16}$ in. and to make connection with the spring on the grounded steel bar of the distributing frame thereby leading the excess current to ground and protecting the telephone apparatus.

It is made up of two distinct sections, namely an operating room, fig. 7,529, and a terminal room, fig. 7,530.

The operating room contains an A and a B switchboard, and the terminal room contains distributing frames, relays, fuse panels, storage batteries, charging machines and ringing machines. The apparatus is described in detail in the sections following.

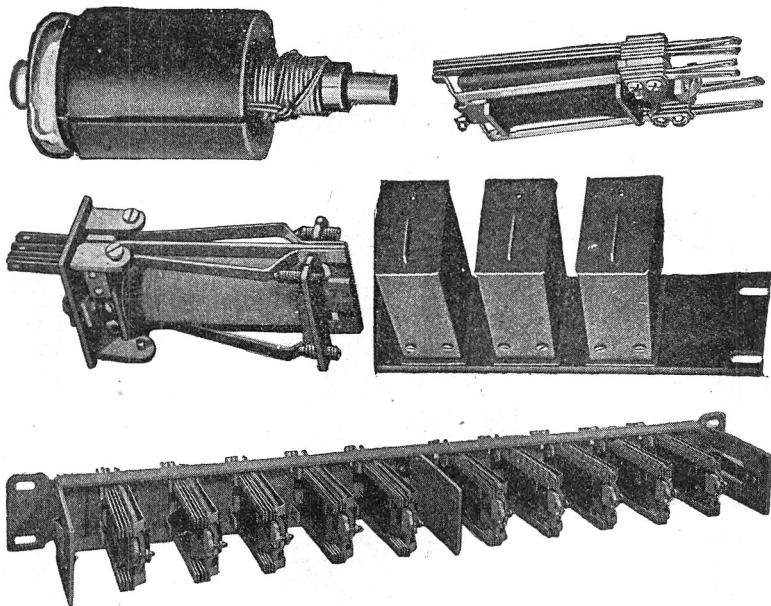


FIG. 7,532.—Heat coil, enlarged view.

FIGS. 7,533 to 7,535.—Various relays. The principle of operation and elementary construction is the same in all. They differ in constructional details, which allow one type to mount in a smaller space, or allow the closing or opening of several circuits in one operation.

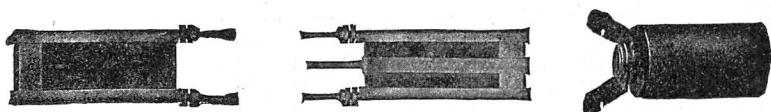
FIG. 7,536.—Relays on mounting plate.

Distributing Frame.—A typical distributing frame is made of structural steel with terminal strips on one side mounted horizontally and terminal strips or heat coil protector blocks on the other side mounted vertically.

The lead covered cable from the subscriber's cable terminal shown in fig. 7,526 is brought to the horizontal side of the Central Office distributing frame, and is connected to the terminal strips as shown in fig. 7,531.

From this distributing frame, or M.D.F., the line wires are led to a second frame, generally called intermediate distributing frame, or I.D.F., where cross-connections are made to terminal strips containing cable wires to line and cut off relays, and to the multiple jacks on the "B" switchboard.

The Relays.—As used in telephone circuits the relays are of various types, some of which are shown in figs. 7,533 and 7,534, and are generally mounted on mounting plates, as in figs. 7,535 and 7,536, which are installed on *relay racks*, the latter being iron I-beams vertically supported and drilled for the mounting plate holding screws



FIGS. 7,537 to 7,539.—Flat and round type resistances made of German silver, or other similar wire, wound on mica or asbestos.

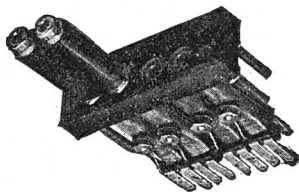


FIG. 7,540.—Jacks mounted in a hard rubber jack mounting.

Resistances.—For telephone circuits resistances are of the flat type as in figs. 7,537 and 7,538. They are used to take up the excess voltage in connection with the operation of relays or the lighting of lamps on switchboards. Resistances are also mounted on mounting plates with the associated relays on the relay racks.

The B Switchboard.—As previously mentioned, the subscriber's line is connected by means of cable from the I. D. F., in the terminal room to the B board in the operating room. At the B board the line terminates in a *multiple jack* located in a jack panel in front of an operator.

Each operator can reach 10,000 jacks. In order to locate so many jacks within the reach of an operator, 20 of these jacks are moulded in a hard rubber strip about 10 to 12 ins. long, and these jack strips are piled up one over the other.

Each pile-up of jacks is known as a jack panel and there may be as many as 1,500 jacks in each panel, as shown in fig. 7,541

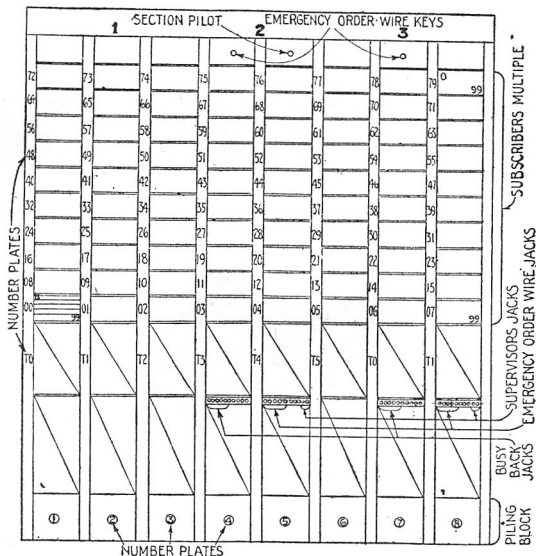
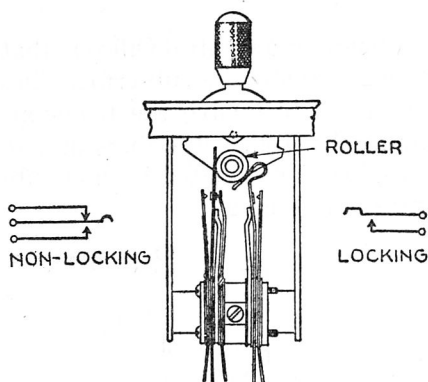


FIG. 7,541.—Face equipment of a B board section. In each section there are seven jack panels, and each jack panel has a capacity of 1,500 jacks. Each rectangle above represents a group of 100 jacks and each group is designated on the stile strip as 00, 01, 02, 03, 04, — 64—65—98—99, etc. The jacks in each group are marked from 00 to 99 inclusive so that by taking the number on the stile strip plus the jack number it indicates the particular subscriber's line associated, as 65+86, or telephone line No. 6586. The numbering is permanent for the life of the Central Office, and if a jack becomes defective, it must be disconnected and removed and a new jack put in its place.

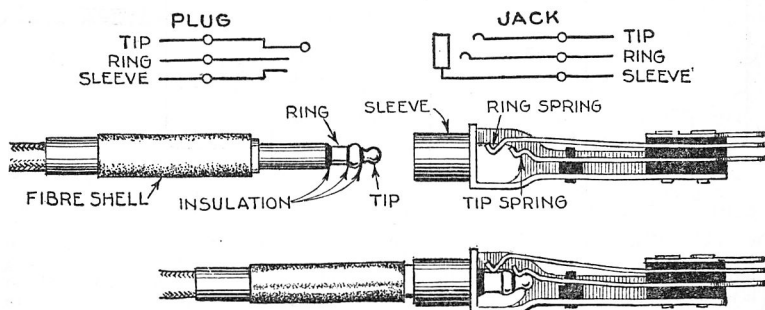
Connections to the jacks are made by means of cords, which are known as *trunks*, as shown in figs. 7,545 to 7,549.

Ques. What is the function of the B operator?

Ans. She connects a calling subscriber with a telephone within her Central Office area.



FIGS. 7,542 to 7,544.—Details of lever type key.



FIGS. 7,545 to 7,549.—Jack and plug details showing how connections are made by inserting a cord plug into a jack. Each jack has three contacts known as tip, ring, and sleeve, and the cord plug has tip, ring and sleeve to correspond. Hard rubber is used for insulation of the contacts.

Incoming Trunks.—The operator completes the connection by inserting a cord plug into the jack of the desired line. When the cord is in the jack a relay associated with the cord circuit connects generator current and rings the bell of line called. The cord circuit at the B board is known as an incoming trunk,

and is connected to a jack on the A board of a distant Central Office, as shown in fig. 7,550.

The A Switchboard.—The A board in a Central Office is that part of the operating switchboard where the subscriber lines and outgoing trunks are terminated to enable the telephone operator to receive signals and calls from subscribers and to make the first connections on all calls originated by any subscriber in that particular Central Office area.

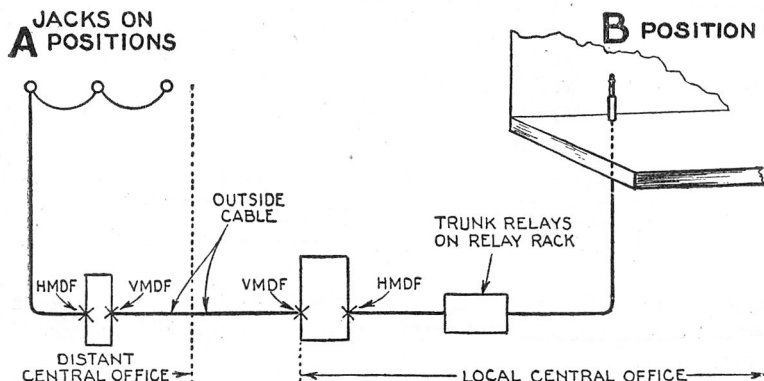


FIG. 7,550.—Diagram of trunk between A and B boards. The A board end is known as *outgoing trunk* (or O. G. T.), and is connected to a jack which is repeated on the face of the A board at every 6, 7 or 8 panels and the trunk is multiplied to each jack. The B board end is terminated as a cord and is known as *incoming trunk*. There are relays associated with each trunk circuit, and these relays are generally located on relay racks in the terminal room. The incoming trunk cord is located at only one specific position of the B board.

The A board consists of sections, each of three operator positions, equipped with cords and jacks, and arranged to form a straight line, as in fig. 7,551, or a regular curve. It is similar to the B board in the construction of the wooden frame work and the design of the panels.

Answering and Trunk Jacks.—The jack equipment in the jack panel of the A board consists of the subscriber's answering jacks at the bottom, the multiple answering jacks above them,

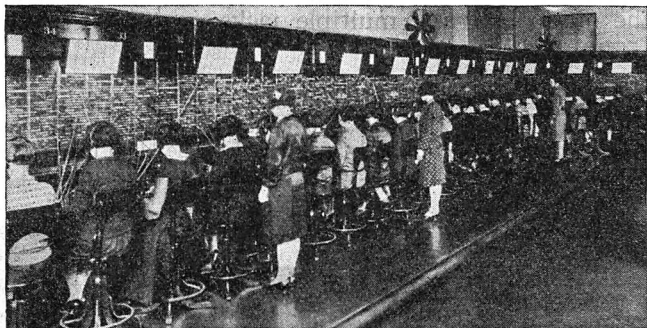


FIG. 7,551.—Typical A board in operation.

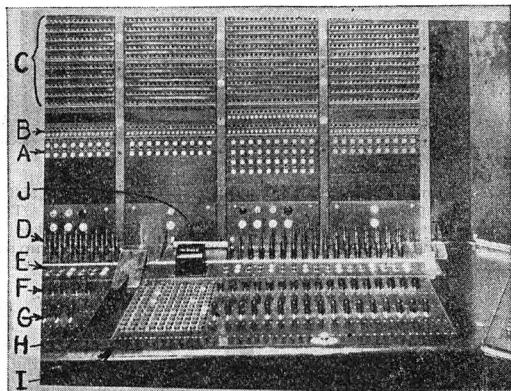
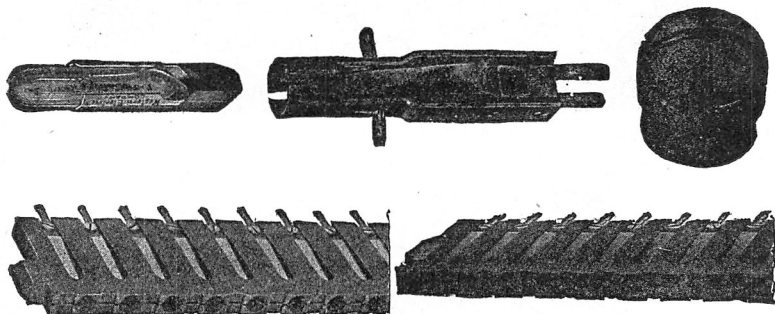


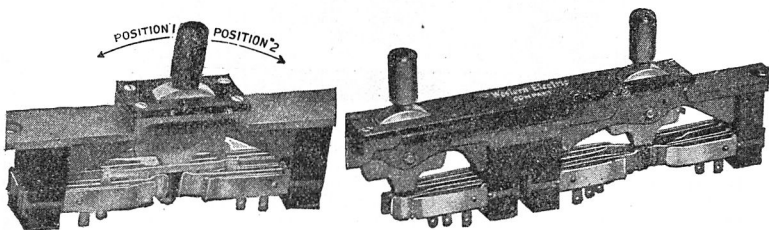
FIG. 7,552.—An A Board position. **Legend:** A, subscriber answering jacks and lamps; B, subscriber multiple answering jacks and lamps; C, outgoing trunk multiple (jacks only); D, connecting cords. There are two cords to each cord circuit, a front and a back cord. The back cord is used to answer and is inserted into the answering jack and the front cord is always inserted into the outgoing trunk jack; E, cord supervisory lamps, two to each cord circuit, one lamp for the back cord and one lamp for the front cord; F, message register key which when pressed operates a meter to register the call made by a subscriber; G, ringing and talking key. When tipped forward this key places ringing current to the front cord and when tipped backward the same key connects the operator's telephone set to the cords for talking and listening (key details shown in fig. 7,558); H, pad holder to hold a small pad on which the A operator writes the number calling and the number called with the time in case an extra charge is to be made for a connection; I, call circuit buttons. Each of these keys when pressed connects the A operator with a distant B operator. Each key represents a distant central office (B board); J, position clock, operated by electricity and shows the time in six second intervals.

and the outgoing trunk multiple jacks on top, as shown in fig. 7,552.

Each answering jack has below it a small lamp, shown in figs. 7,553 to 7,557. The answering jack and its lamp are connected to the subscriber line and cut off relays previously mentioned. The lamp lights when the receiver is removed from the hook at the telephone station associated with it.



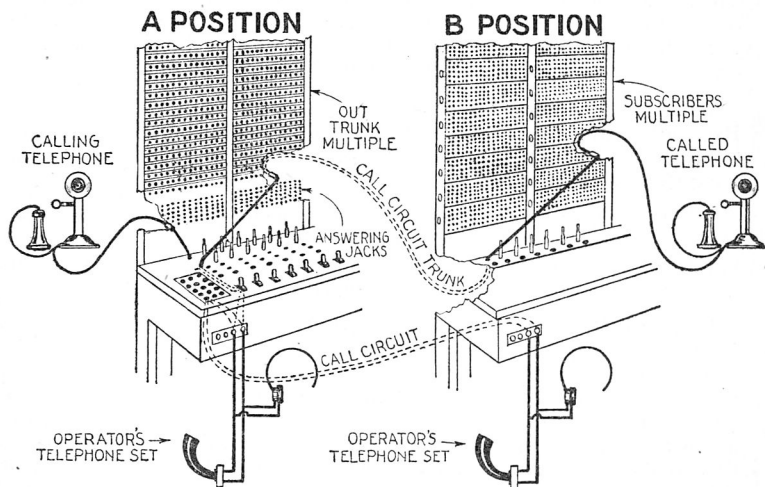
FIGS. 7,553 to 7,557.—Miniature electric lamp and parts. The lamp fig. 7,553 fits into socket; fig. 7,554, and the lamp cap fig. 7,555 fits at end of lamp socket. The glass of the lamp cap may be white opalescent, red, or green, or it may be marked with black bars or a dot. Figs. 7,556 and 7,557 shows hard rubber strips fitted with lamp sockets similar to the one of fig. 7,554.



FIGS. 7,558 and 7,559.—Switchboard keys. In order to meet the needs of every calling subscriber, the operator must perform several different acts in shifting and changing circuits and to facilitate this work, devices to simplify it as much as possible have been developed. The modern keys have greatly helped in the saving of the operator's time. By throwing the little levers a hard rubber bushing makes or breaks the contacts at the springs and throws alternating current ringing power into the line. When the finger pressure is released, the levers fly back again into normal position. The keys may be arranged to operate in the opposite direction for talking and listening purposes.

Keyboard.—On the keyboard of an A position are 17 pairs of cords, 17 keys to ring and talk, 17 register keys and 17 pairs of supervisory lamps. In addition there are a number of call-circuit keys.

Cord Circuits.—There are 17 cord circuits in each A position. Each cord circuit is composed of one pair of cords, one pair of lamps, one key to ring and talk and one register key.



FIGS. 7,560 and 7,561.—Diagram of operation showing calling and called telephone and the Central Office A and B boards. The B board is assumed to be in a distant Central Office. It may, however, be located in the same Central Office as the A board in which case it serves to complete calls to subscribers in the same Central Office area.

Operation.—By referring to figs. 7,560 and 7,561 the operation for a telephone connection is made clear. Both the A and B boards are involved in every telephone connection, be it local or over a long distance.

Assume that the calling number is Stuyvesant 2997 and that the desired party has telephone number Bensonhurst 7813.

The A board will be located in the Stuyvesant central office and the B board in the Bensonhurst Central Office.

The calling party lifts the receiver off the hook and causes a lamp to light on the A board.

The A operator sees this light and inserts a back cord into the answering jack associated with the lighted lamp causing the lamp to be extinguished. The A operator says "Number please" and the calling party replies "Bensonhurst 7813." The A operator then says "Thank you," and presses a call-circuit button marked *Ben*, which connects her with the B operator who will complete the connection in the Bensonhurst Central Office.

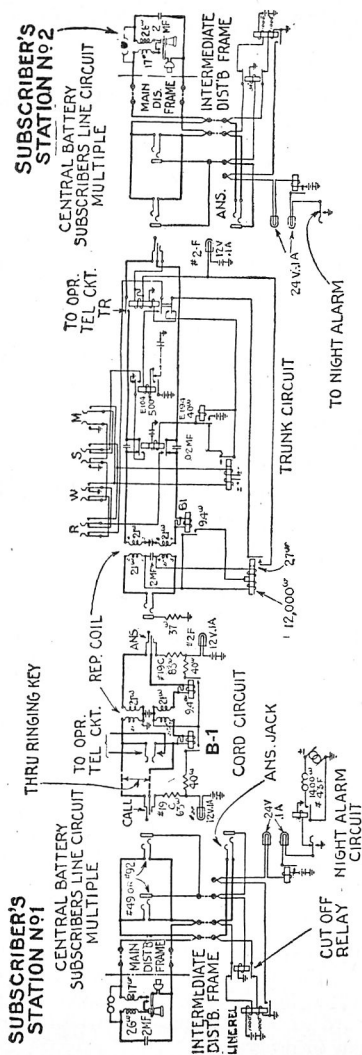
When the A operator has pressed the call circuit button she says to the B operator "Stuyvesant 7813" meaning that she is located in the Stuyvesant Central Office and desires a trunk connection to line No. 7813 in the Bensonhurst Central Office area.

The B operator assigns a trunk to the A operator, and simultaneously picks up the cord associated with the trunk she has assigned and inserts it into the jack marked 78-13. The A operator picks up the front cord of the pair she started with and inserts the plug into the outgoing trunk jack.

Before the B operator inserts the incoming trunk cord into line jack 78-13 she makes a busy test by touching the tip of the cord to the sleeve of the jack. If the line be busy at that moment, she receives a click in her head receiver, and instead of completing the connection, she inserts the cord plug into a different jack designated *busy*. This sends interrupted ground and a *busy tone* back to the A board, causing the front cord supervisory lamp to flash at the rate of sixty times per minute, which tells the A operator that the line called is busy. The calling party meanwhile hears the *busy tone* and hangs the receiver back on the hook. If he do not hang up, the A operator will advise him to do so by saying "I am sorry, but the line is busy."

If the line called be not busy, the B operator inserts the trunk cord into jack 78-13 and causes ringing current to be sent out automatically to ring the bell. When the called party answers, the ringing current is also automatically disconnected and the circuit is ready for talking

While the conversation is in progress, the cord supervisory lamps are not lighted. The instant the receiver is replaced on the hook, the corresponding cord supervisory lamp lights on the A board and the A operator disconnects.



Figs. 7,562 to 7,565.—Typical telephone circuit showing calling subscriber line circuit, A board cord circuit, trunk circuit and called subscriber line circuit. The calling subscriber is located in the area cared for by the A board. The called subscriber is located in the area cared for by the B board. The A and B boards may or may not be in the same building and may be any distance apart.

If one end of the line should move the hook up and down slowly, the cord supervisory lamp in fig. 7,563 will flashto attract the attention of the A operator. The B board does not get this flash.

When the A operator has removed the trunk cord from the O.G.T. jack, at the end of the conversation, she causes the lamp on the B board associated with the trunk cord, to light, whereupon the B operator removes the cord from jack 78-13 and restores the trunk to normal for another connection.

The Complete Circuit.—The foregoing operation is made possible by the circuit shown in figs. 7,562 to 7,565. There are four main parts to this circuit:

1. The calling subscriber, fig. 7,562;
2. The local A board cords, fig. 7,563;
3. The trunk, which connects the local A board with the distant B board, fig. 7,564;
4. The called line at the distant end, fig. 7,565.

Making a Telephone Call.—The calling subscriber originates the call by lifting the receiver off the hook. This causes the line relay to operate and to connect ground to the line lamp, lighting it. The A operator upon seeing this light inserts the cord plug (call) into the answering jack above the lighted lamp.

The insertion of the plug into the jack causes the current to flow from the cord supervisory lamp to the *sleeve* of the cord plug, to the sleeve of the answering jack, and through the winding of the cut off relay causing this relay to operate and to extinguish the line lamp. The cord supervisory lamp does not light because it is short circuited through the contacts of relay B-1, which is operated.

After obtaining the information from the calling subscriber and also a trunk assignment from the B operator, the A operator inserts the *Ans* plug into the outgoing trunk jack. The supervisory lamp associated with this plug is now lighted since the B-1 relay of this plug has not yet operated, and will not be operated until the called party answers the telephone.

At the distant B board, the B operator takes the cord of the trunk assigned to the A operator and inserts it into the multiple jack of the line desired. If there be party lines in that Central Office, she depresses the proper party ringing key R.W.S., or M, before inserting the cord plug into the jack.

The bell at the called station now rings. The *disconnect* lamp at the B board is not lighted, and will not be lighted until the A operator disconnects.

When the called party answers, the ringing current is automatically disconnected and a path is completed for the electric current which causes the operation of the B-1 relay in the trunk, fig. 7,564. This causes the *Ans* cord supervisory lamp at the A board to be extinguished, advising the A operator that the conversation is now in progress.

At the end of the conversation the parties *hang up*, and each causes the associated B-1 supervisory relay to release and thereby light the corresponding cord lamp, advising the A operator that she may now take down the connections which she does and causes the *disconnect* lamp of the trunk to light at the distant B board. This signifies to the B operator that she may withdraw the trunk cord plug from the multiple jack, which she does, and restores the circuit to normal.

The "night alarm" shown in fig. 7,562, is used only when the switchboard is managed by a few operators, as at night.

When used, the night alarm relay, which operates when the answering lamp lights, causes the bell to ring to call the attention of the night operator who may be handling a connection at some other part of the switchboard. The bell stops ringing as soon as the operator answers the call.

Straight Forward Method.—A later development enables a trunk connection to be made in less time. This method eliminates the call circuit between the A and B operators and is termed *straight forward method*. Instead of asking for a trunk assignment from the B operator, the A operator picks out an idle trunk to the B board, and inserts the cord plug into the corresponding jack.

This causes the trunk lamp at the B position to light showing that there is a call waiting on that trunk. The B operator's telephone is then automatically connected to the same trunk and two short tone impulses are transmitted to the A operator, indicating that the B operator is ready to receive a call.

At the same time the steady trunk lamp at the B board changes to a flashing signal which aids the B operator in locating the trunk to which she is connected in case several trunk lamps are lighted at one time. The A operator then passes the number desired to the B operator who then makes the usual busy test.

If the line be idle she inserts the plug into the multiple jack, thereby extinguishing the flashing trunk lamp. The remaining operations are as previously explained for fig. 7,562.

Call Indicator Method.—On calls originated by subscribers in dialing central office areas, the connections are made by automatic switching apparatus, as explained in the next chapter.

In order to complete calls from subscribers in dial Central Office areas, the B board contains several positions which are known as *call indicator positions*. These are similar to the one shown in fig. 7,566, and differ from the regular manual positions only in the equipment of the keyboard, which contains a small metal box with a glass plate known as *call indicator* and upon which are printed five groups of digits known as:

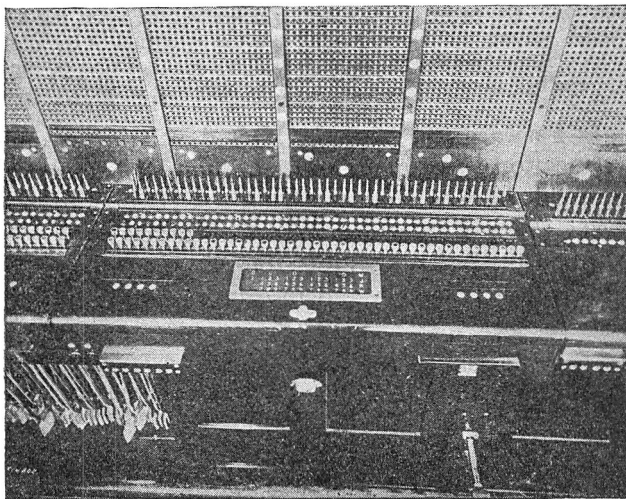


FIG. 7,566.—Typical call indicator position of a B board. The jack panels of these positions are equipped with subscriber multiple jacks like the rest of the positions on the B board. The *call indicator* box is mounted flush with the top of the keyboard.

1. Ten thousands;
2. Thousands;
3. Hundreds;
4. Tens;
5. Units.

The ten thousands group contains just 0 and 1. The other four groups have all ten digits from 0 to 9. There may also be letters for party designations. The metal box contains from 42 to 46 miniature lamps which are arranged so that each number or letter has a lamp underneath.

There is in addition at each position a control circuit composed of a number of relays. The function of the control circuit is to receive the pulses coming from the mechanical sender of a dial Central Office, as described in the next chapter.

The pulses cause the relays in the control circuit to operate in certain combinations which light the proper lamps on the *call indicator* and cause the number desired to be displayed on the glass cover. The B operator sitting at this call indicator position then takes the trunk cord over which the pulses were sent and inserts its plug into the jack corresponding to the number displayed on the glass plate, first however making the usual busy test.

When the connection has been made by the B operator the number displayed is automatically *wiped out*. The operations from this point on are the same as those explained for fig. 7,562.

Manual Private Branch Exchanges.—It is often necessary in the case of business offices, hotels, department stores and similar establishments, to have more than one telephone station and to arrange these stations so that each may call the other as well as call the Central Office to transact business. For this purpose there have been developed several types of manually operated switchboards which are located in the subscriber's premises and which are known as Private Branch Exchanges or P.B.X.'s.

These P.B.X.'s are connected to the telephone Central Office by means of lines called *trunks*, and have extension lines radiating to the various extension stations in the subscriber's establishment, as indicated in fig. 7,567.

The type of P.B.X. switchboard to be installed for a particular case depends upon the service requirements, such as the number of Central Office trunks, the number of extension stations and the amount of traffic to be handled.

The manual P.B.X. switchboards may be divided into two general classes:

1. Multiple.
2. Non-multiple.

In the multiple type the extension lines and the Central Office trunks are repeated along the face of the switchboard at every four panels, so that a call coming into the switchboard will simultaneously cause a lamp to be lighted at every appearance of that particular line and allow some operator, one who is not busy at that moment, to answer the call. This feature enables the switchboard to be made up of any number of operating positions up to the limiting quantity.

In the case of the non-multiple switchboards, the extension lines, and the Central Office trunks appear at only one spot on the face of the switchboard. This limiting device means that switchboards of this type are made up of a few operating positions, and are designed to fulfill a lighter demand for telephone service.

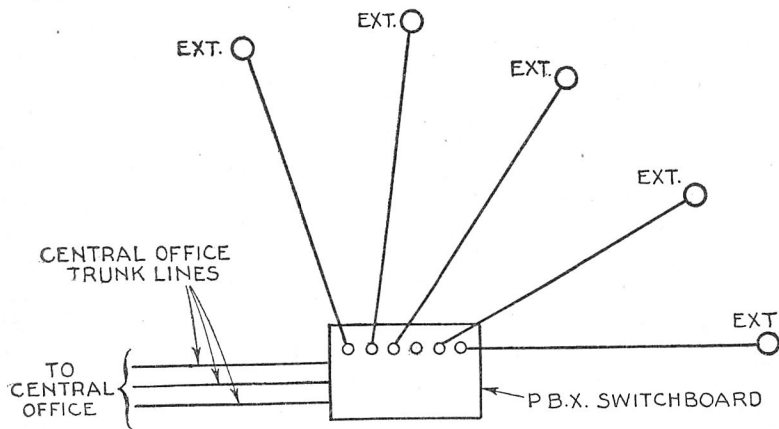


FIG. 7,567.—P. B. X. system.

Cordless Type Switchboard.—This is the smallest P.B.X. switchboard made and has keys as shown in fig. 7,568, instead of cords to make the connections. It consists of a small wooden box, the one shown being approximately 16 ins. wide by 15 ins. deep by 14 ins. high, and contains several keys, magnetic drop signals, hand generator which is used to ring the extension bells whenever the regular Central Office generator supply fails, and a telephone set.

Operation of Cordless Type Switchboard.—On connections between two extensions or between an extension and a Central Office trunk line, the two associated keys in the same horizontal row must be operated to the same up or down position, so as to bridge the two lines.

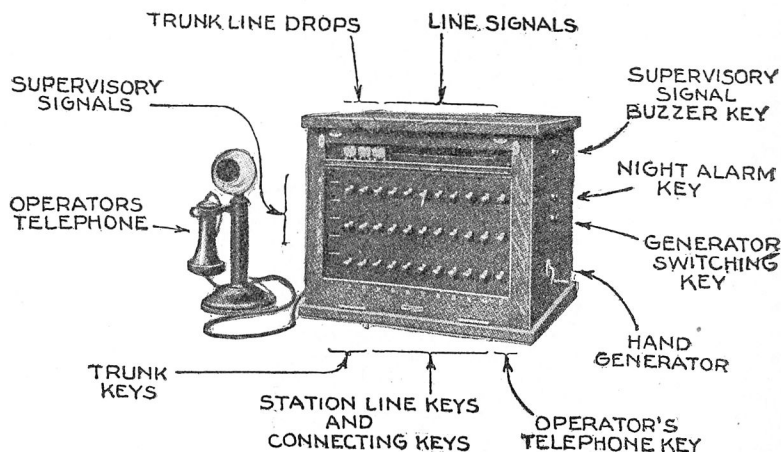


FIG. 7,568.—Cordless type P. B. X. switchboard. There are 3 rows of keys with 11 keys of the cam lever type in each row as follows: 3 keys for central office trunk lines (first 3 keys at left side), each with a trunk line drop above (details of drops shown in fig. 7,528), 7 keys for extension lines (keys 4 to 10), each with a magnetic line signal above; 1 key for the operator's line (last key at right). The keys provide for 5 simultaneous connections.

If one of the lines called be on a local extension, the ringing key in the bottom row associated with the called station must be held operated in the down position to ring the bell.

If two keys in the same horizontal row be operated to the same *up* position, two other keys in the same horizontal row may be operated in the *down* position, or vice versa, for a second connection.

Each of the five *up* and *down* positions on the horizontal row of keys has a magnetic supervisory signal mounted at the left of the keys in a vertical row. This operates as a disconnect signal when the receivers are placed on the switch hook and it may also be used to flash under the control of an extension at which the hook is being moved up and down.

Calls originated at one of the extensions are indicated by the operation of the associated magnetic line signal on the top row, which is restored to normal when the operator answers the call.

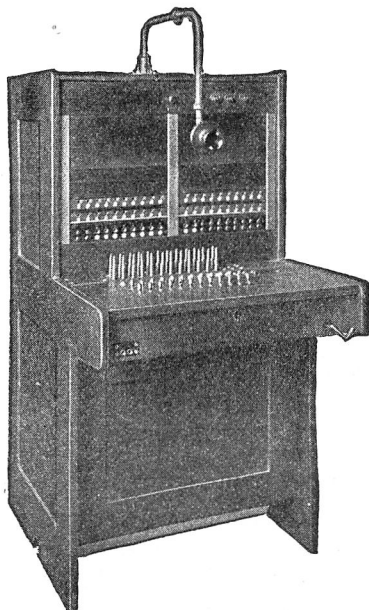


FIG. 7,569.—Cord type P. B. X. switchboard. Each extension jack and each trunk jack is equipped with a line lamp which lights when a call comes into the switchboard. The cords have supervisory lamps which light when the conversation is over and the receivers at the respective telephone stations are *hung up* to indicate to the P. B. X. operator that the connection may be taken down. The ringing key in each cord circuit has generator current from the Central Office to ring the local extension bells. If this generator supply should fail a small hand generator is equipped to furnish the necessary alternating current.

Calls coming from the Central Office are indicated at this P.B.X. by the operation of the associated trunk drop which has to be restored by hand after the call has been answered.

The necessary battery to operate this P.B.X. and the generator current to ring the extension bells is furnished over separate feeders from the Central Office. The hand generator is used to ring the extension bells only in case of failure of the Central Office supply.

Cord Type P.B.X. Switchboards.—These are equipped with cords to make the connections and have lamps and jacks similar to the Central Office switchboards. They are made in various sizes depending upon the specific needs. The one

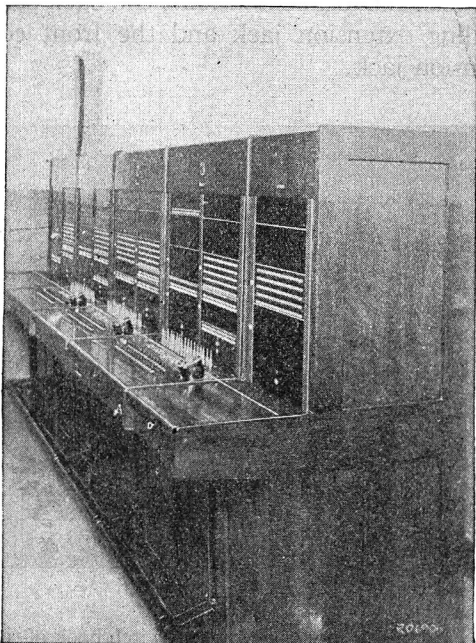


FIG. 7,570.—Multiple cord type P. B. X. switchboard of three positions. Note the dial on each position; this is made necessary since the P. B. X. is connected with trunk lines to a dial central office. The capacity of this switchboard without increasing the number of positions is approximately 500 lines.

shown in fig. 7,569 has a capacity of 80 extension lines, 15 central office trunks and 15 cord circuits (15 pairs of cords).

All the relays, resistances and retard coils of the cord and trunk circuits are mounted on a swinging gate in the rear of the switchboard.

Operation of Cord Type P.B.X. Switchboards.—The cords are arranged in pairs and are used to make all connections. There are two lamps associated with each pair of cords, and a set of listening and ringing keys. When connections are to be made between the local extensions, the back cord is inserted into the calling extension jack and the front cord into the desired extension jack.

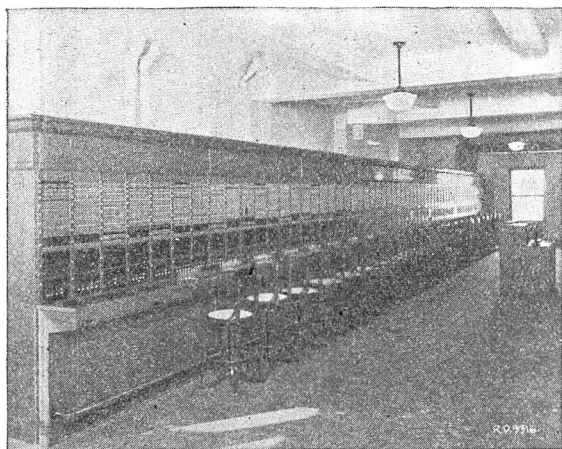


FIG. 7,571.—Large manual P. B. X. switchboard.

The rear cord lamp is controlled by the switch hook of the calling extension and the front lamp by the switch hook of the called extension. On connections with central office trunks, the back cord is put up on the extension jack and the front cord on the trunk jack.

When a call comes into the switchboard, the lamp associated with the circuit lights. The operator then inserts the cord into the jack above the lamp and causes the light to be extinguished.

The operator, by tipping the respective key of the cord pair, can talk to the extension. By tipping the key to the *ring* position, generator current is

applied to the cord, which, if inserted into an extension jack, causes the extension bell to ring. The ringing is manually controlled by the operator.

Large P.B.X. Switchboards.—Some P.B.X's have a capacity of 4,000 lines and are made up of as many as 40 operating

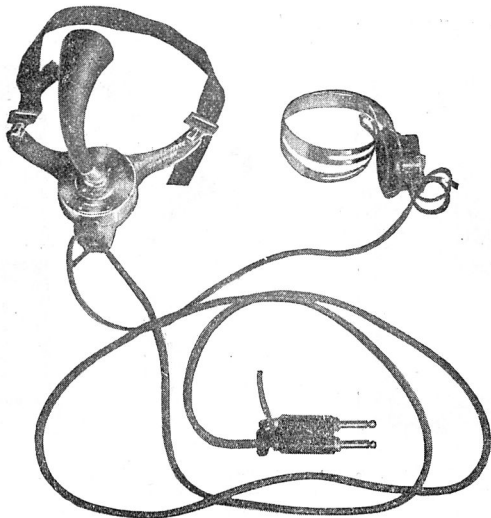
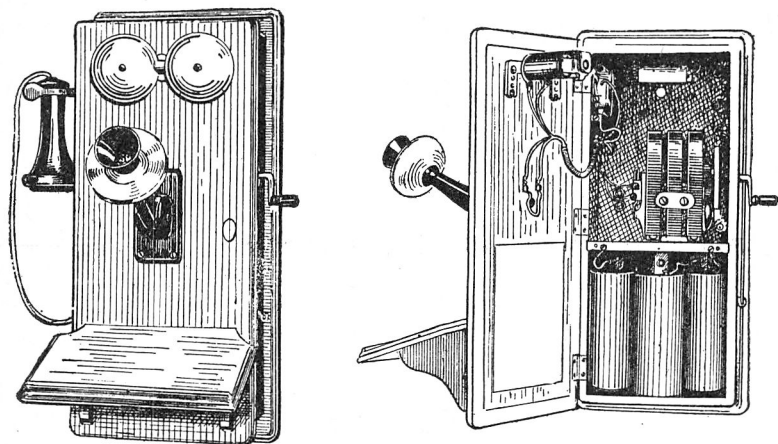


FIG. 7,572.—Operator's equipment showing receiver, transmitter, cut in plug, etc. The chest plate transmitter equipment is shown with cords connecting it to a cut in plug and a head receiver. The horn shaped mouthpiece is made of hard rubber and can be removed. The chest transmitter is held in place by a cloth neck band, the receiver by a head receiver band and the plug is inserted in spring jacks which are connected with the operator's set.

positions. In these cases the switchboard is the same as the one used in the telephone Central Offices and requires similar main distributing frame, relay racks, and a large power plant consisting of a storage battery, charging machine, and a power board. One such P.B.X. switchboard is shown in fig. 7,571.

Operator's Telephone Set.—All telephone operators, in the central offices as well as in P.B.X's, have a head receiver and

chest transmitter connected to a double plug as shown in fig. 7,572. When in use the plug is inserted into a double jack at the switchboard position in the manner indicated in figs. 7,560 and 7,561.



FIGS. 7,573 and 7,574.—Magneto set telephone; views showing case closed and open. The transmitter connections are made of stranded copper wire with a double silk insulation. These wires lead from the transmitter through the hollow arm to the inside of the door. From here one wire goes to one terminal of the battery and the other is soldered to a connector to which is already attached a wire that is carried through a slot in the back board to the primary winding of the induction coil. The set complete is made with all parts of the circuit and all wires well insulated.

Magneto System.—A magneto telephone is shown in figs. 7,573 and 7,574 which employs two or three dry cells at each telephone to supply the necessary talking battery instead of using a *common battery*.

This instrument is used in the so-called magneto telephone system where each telephone user signals or calls the telephone exchange or other telephones on the line by turning the crank of a small hand generator or magneto. This system has been made obsolete by the development of the common battery system, and is used only in small isolated plants.

Carrier Current Telephone System.—In the previous description of the telephone it was mentioned that for each conversation two wires were utilized. Where it is required to transmit telephone messages over long distances it is sometimes necessary to employ one of the long lines, or toll line, to carry more than one conversation in both directions simultaneously without interference with one another. This method is known as *Multiplex Telephony* or *Carrier Current Telephone System*.

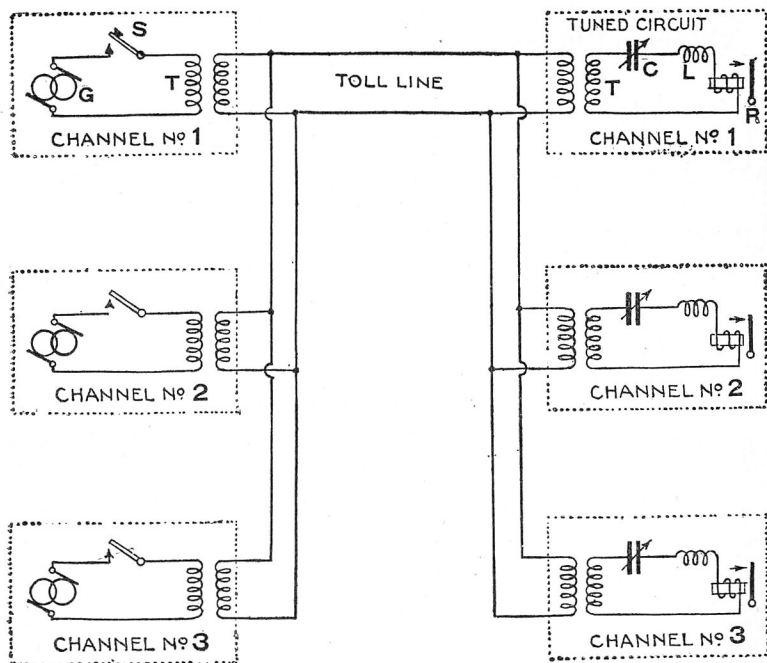


FIG. 7,575.—Simplified Multiplex circuit, **consisting of three channels**, each equipped alike and arranged to operate simultaneously over the same toll line. Each sending station is equipped with a high frequency generator G, a sending key S and a repeating coil T. Each receiving station is equipped with a repeating coil T, a variable condenser C, an inductance L, and a sounder relay R.

It is accomplished by superimposing on the same pair of wires a number of alternating currents, each of different frequency and each controlled to carry a particular telephone conversation.

The method of operation of this system is illustrated in the simple diagram, fig. 7,575.

The illustration shows three different channels, or stations, using the same toll line simultaneously. Each channel is equipped the same, except that the generator *G* has a different frequency for each channel. By operating the sending key *S*, signals of frequency *G* are transmitted over the toll line which are picked up at the receiving end by the tuned circuit which

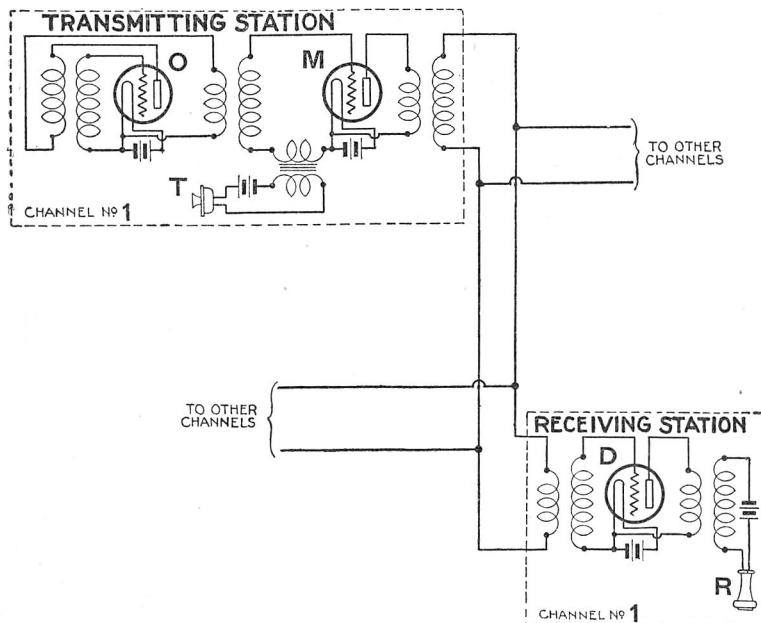


FIG. 7,576.—One channel of a carrier current telephone circuit *the transmitting station consists of:* O, vacuum tube oscillator circuit, which generates the high frequency carrier current; M, vacuum tube modulator circuit, which impresses the voice currents on the carrier current; T, transmitter. *The receiving station consists of:* D, vacuum tube demodulator circuit, which separates the voice currents from the carrier current wave; R receiver which reproduces the speech.

is adjusted in *resonance* with the frequency of G. Similar operation of the channels No. 2 and No. 3 cause signals of other frequencies to be sent over the same toll line at the same time.

At the receiving end, however, each tuned circuit, being adjusted in resonance to the respective generator frequency will pick up messages only from its own sending station. The tuned circuits are made very *selective* so that no interference results between the three messages.

The elements illustrated in fig. 7,575 are employed in the present type carrier current telephone system, except that instead of using the key to produce the messages, the ordinary subscriber transmitter is used to *modulate* the high frequency current of generator G. The generator may be a small mechanically driven alternator built as a unit with the driving motor, capable of supplying as many as twelve channels in the voice frequency range of 400 and 2,500 cycles per second; or it may be the ordinary three element vacuum tube connected as an oscillator.

The use of the vacuum tube is more desirable on account of its numerous advantages over the mechanically driven alternator. The vacuum tube has no moving parts to get out of order, takes up little room, is very easily adjusted and has a low first cost and upkeep cost.

In fig. 7,576 is shown a simple carrier telephone system employing vacuum tubes.

Operation.—The vacuum tube oscillator O operates similarly to a detector tube with *regeneration* in a radio set. When the *feed back* from

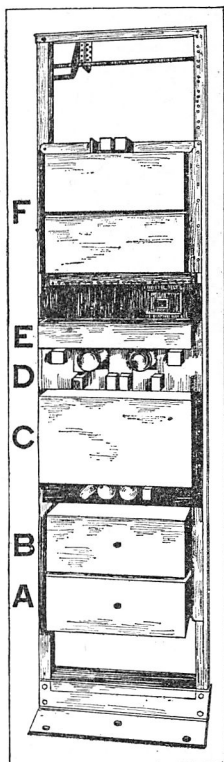


FIG. 7,577.—Typical carrier current unit A, modulator band filter; B, demodulator band filter; C, channel unit consisting of oscillator, modulator and demodulator also shown in figs. 7,578 and 7,579; D, signaling unit shown in fig. 7,580 E, adjusting unit; F, line filters.

the plate circuit exceeds a certain value the tube will cause a *howl* in the radio loud speaker. The howl is caused by *high frequency oscillations* produced by the vacuum tube. In fig. 7,576 the high frequency oscillations produced by the oscillator tube O are of constant current value, and would, of

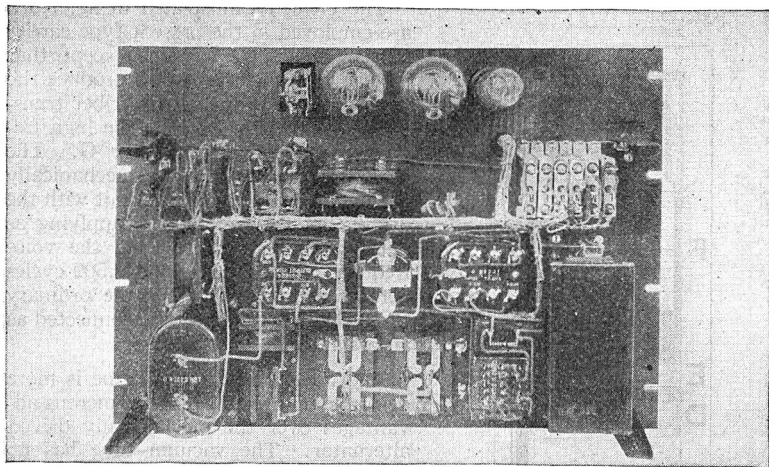


FIG. 7,578.—Front view of channel unit with cover removed consisting of oscillator, modulator and demodulator.

course, convey no information to the receiving end. It is necessary to *modulate*, or to impress upon this *carrier current* the signals, or the conversation.

This is done by using a transmitter in conjunction with another vacuum tube, designated M. The carrier wave undergoes a change as a result of this *modulation*, that is, variations are produced which correspond to the *voice* wave.

The modulated carrier current reaches the receiving set where the demodulator tube D separates the *voice* wave from the *carrier* wave. The demodulator is in reality a *detector* very much like the detector in a radio receiving set.

It must be remembered that other channels, similarly equipped, may be operating and using the same line simultaneously in both directions. However, the oscillator circuit in each channel generates a *carrier* of a different frequency and the associated receiving station is adjusted to receive only at that particular frequency. The several *carrier* currents from the various transmitting stations will not interfere with each other while traversing the common line wires.

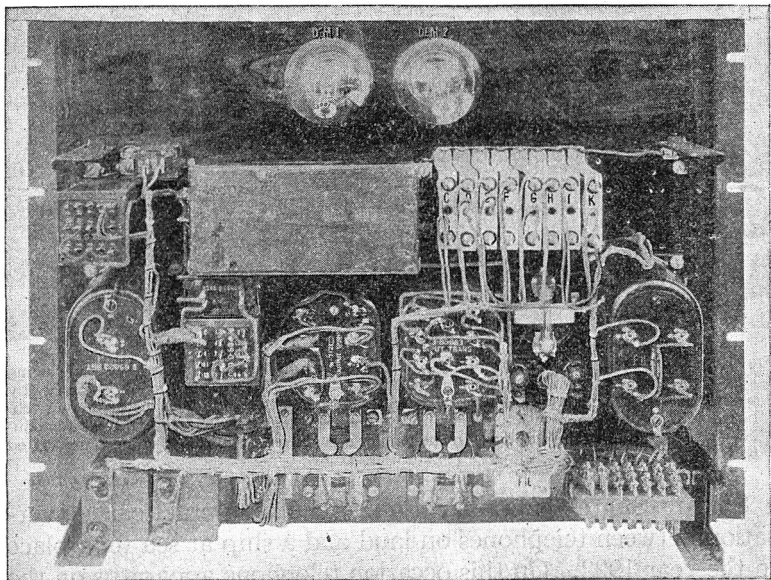


FIG. 7,579.—Rear view of channel unit with cover removed.

Commercial Current Carrier Units.—The commercial types of current carriers are made up in units which are wired and adjusted at the factory. These units are mounted on steel racks and are located in some centralized terminals, such as central offices. They may be wired to jacks which are located on the switchboard of the central office.

Each complete circuit is wired to the distributing frame where by means of cross connection wire connection may be made to a particular toll line and to the switchboard jacks when required. Fig. 7,577 shows the equipment for one circuit, both sending and receiving, with enlarged views of the units in fig. 7,578, 7,579 and 7,580.

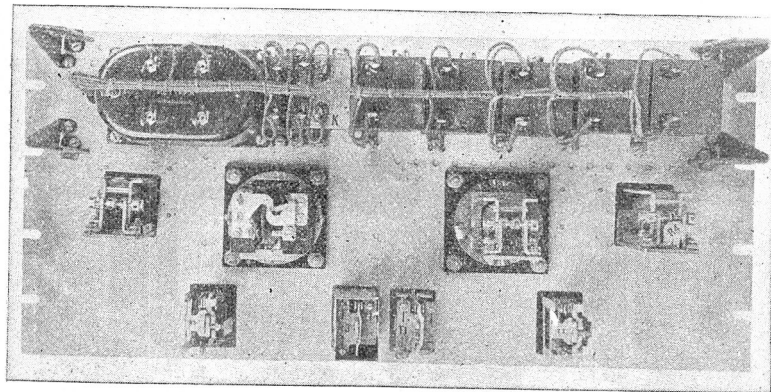


FIG. 7,580.—Front view of signaling unit. When the switchboard operator presses the ringing key at the switchboard, ringing current of 20 cycles is applied to this unit which causes by modulation spurts of the carrier current to be sent out over the toll line to the distant switchboard which is equipped with a similar unit. The signals at the receiving end are demodulated and a series of relays operate in the similar signaling unit causing the lamp associated with the toll line to light.

Ship-to-Shore Communication.—The first practical conversation between telephones on land and a ship at sea took place in the year 1922. On this occasion telephone apparatus on the S.S. America was employed while the ship was 400 miles out in the Atlantic Ocean. Before this date extensive experiments in two way conversation had been carried on between two ships and several cities in the United States.

In order to establish a conversation between a telephone station on land and one on a ship while the latter is on a voyage, *the message is transmitted by wire to a radio station located on or near the coast, thence to the ship by radio* as shown in fig. 7,581.

Likewise, conversation originated at S on the ship is sent by radio and is picked up by the radio station B.S. on land, thence it is transmitted by wire through the central offices to the telephone station L.

The system illustrated in fig. 7,581 is also used to establish telephonic communication between airplanes and land stations. This, however, has not as yet been performed on a commercial basis.

When a ship arrives at a pier, facilities are available to connect the telephone switchboard on the ship and the P.B.X. switchboard of the associated steamship company on land.

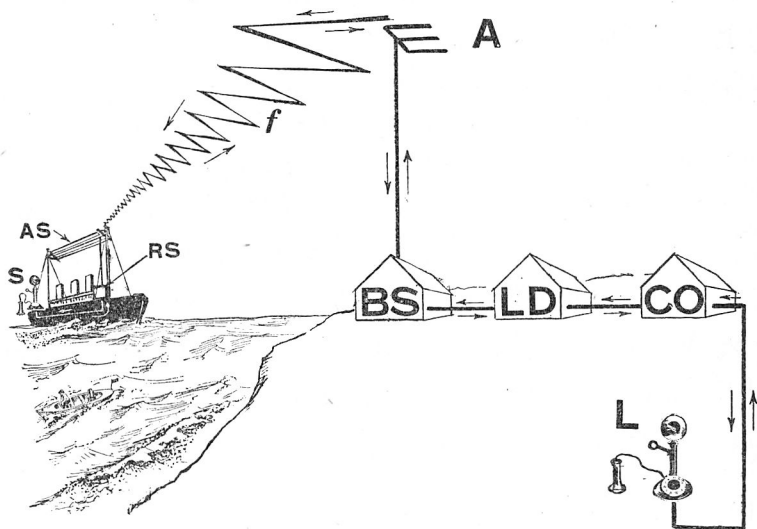


FIG. 7,581.—Ship to shore communication; simplified diagram showing how a telephone conversation is established between a ship at sea and a land station. L, telephone station in a residence or in an office; CO, local telephone central office; LD, long distance telephone exchange; BS, radio sending and receiving station on land; A, aerial on land; f , radio wave; AS, aerial on ship; RS, radio receiving and sending set on ship; S, telephone station on ship.

This is done by means of a portable insulated cable of several pairs of wires which is connected at one end to a terminal box on the pier, and at the other end there is a plug which may be inserted into a multi-circuit jack on the ship. The jack is connected to the telephone switchboard on the ship and the terminal box on the pier is connected to the P.B.X. switchboard on land.

TEST QUESTIONS

1. *Why is it necessary to supply a steady direct current to the telephone transmitter?*
2. *Does the receiver diaphragm vibrate at the same rate as the transmitter diaphragm?*
3. *Why is an iron diaphragm used in the receiver?*
4. *Describe the action in the receiver.*
5. *What will be the result in transmission if the carbon granules in the transmitter stick together?*
6. *What will be the effect upon the receiver if too much current be allowed to pass through the windings?*
7. *Will a bent diaphragm in the receiver cause trouble?*
8. *What will affect the sensitiveness of the receiver?*
9. *What will affect the sensitiveness of the transmitter?*
10. *Can a receiver be used as a transmitter?*
11. *What is the function of the condenser in the subscriber's bell box?*
12. *Describe the operation of the bell.*
13. *State what happens when the receiver is removed from the hook.*
14. *What is the duty of the line relay?*
15. *What is the duty of the cut-off relay?*
16. *Describe the A-board and explain its function.*
17. *Describe the B-board and explain its function.*

18. *Explain how a connection is established between the calling and called subscriber.*
19. *What is meant by "straight forward operation" of trunks?*
20. *How does the heat coil protect a telephone line?*
21. *Mention one serious trouble that will cause a large number of answering jack lamps to light on the A-board.*
22. *If a call circuit become inoperative how is the connection established between the A-board and the distant B-board?*
23. *What will happen if the ringing machine fail in a particular Central Office?*
24. *When does the A-operator take down the connection at the A position?*
25. *What indicates the end of conversation between two subscribers?*
26. *Can the A-operator talk to the calling party?*
27. *Can the A-operator talk to the called party?*
28. *Can the B-operator talk to the A-operator?*
29. *Can the B-operator talk to the called party?*
30. *When does the B-operator disconnect the trunk cord from the subscriber's multiple jack?*
31. *Who disconnects first, the A- or the B-operator?*
32. *What may cause a premature disconnection at the A or at the B-board?*

TEST QUESTIONS*Carrier System*

1. What is resonance?
2. What will be the effect upon transmission if one of the line wires of fig. 7,575 become grounded?
3. If the receiving circuit of channel No. 1 in fig. 7,575 be tuned exactly half-way between the frequency of channel No. 1 and the frequency of channel No. 2 what effect will it have upon the reception of channel No. 1?
4. Draw a simple diagram of a double channel two way carrier circuit.
5. Draw a diagram of a vacuum tube oscillator and describe its operation.
6. What is modulation of a carrier?
7. Explain how the carbon button transmitter could be used to modulate a carrier current.

CHAPTER 186

Inter-Communicating Telephones

(Inter-Phones)

Inter-Communicating Telephones.—Inter-communicating or inter-telephones are those in which calls are made directly at each station without the aid of a P.B.X. operator, that is, each telephone has its own switchboard attached. Inter-phones are desirable in mills, factories, apartment houses, stores, office buildings, etc. Figs. 7,582 and 7,583 show two types of inter-phones.

An inter-phone system works as follows:

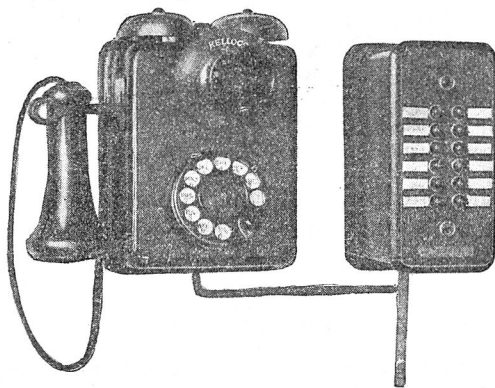


FIG. 7,582.—Kellogg 11 station automatic, wall type inter-communicating telephone.

The pressing of any of the buttons rings a particular station, and when the finger is removed from the button, it falls back on the talking circuit, connecting the system with the station desired.

When through talking with this station and another station is desired, the pressing of the other button restores to its normal position the station that has just been connected, as each button is arranged to automatically restore or release the other buttons.

When the conversation is completed, the placing of the receiver on the hook restores whatever button may have been in use.

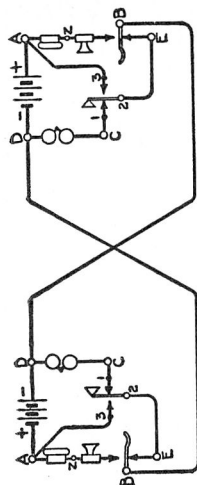


FIG. 7,583.—Kellogg 11 station desk inter-communicating telephone.

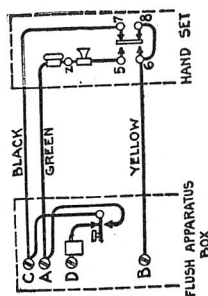
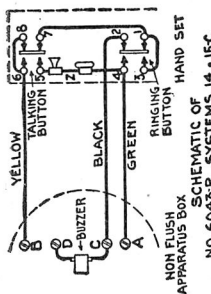
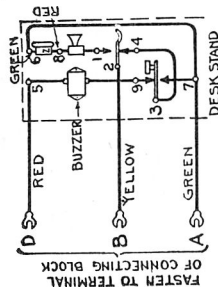
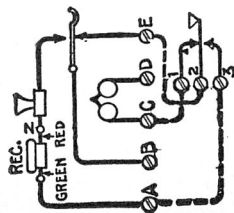
To meet the different conditions in home and business, various inter-phone systems have been designed, which differ in the number of instruments that can be connected, the kind of service they will give, etc.

The systems in general use are:

1. Two station; private line.
2. Code ringing; common talking.
3. Selective ringing; common talking.
4. Selective ringing; selective talking.

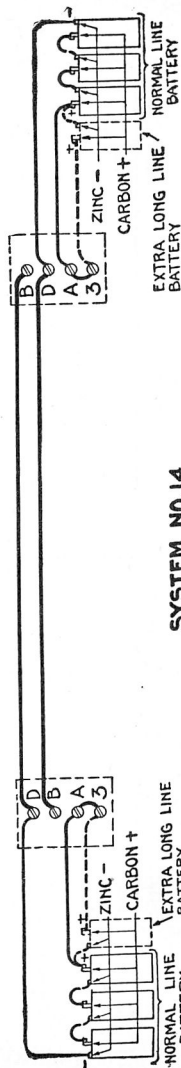


SCHEMATIC WIRING DIAGRAM - SYSTEM NO. 14

SCHEMATIC OF
NO. 6042-AE & AF SYSTEMS 14 & 15CSCHEMATIC OF
NO. 6043-P SYSTEMS 14 & 15CSCHEMATIC OF
NO. 6034-BE SYSTEM-14 & 15CSCHEMATIC OF
NO. 1527-C1 & 1539-C1
SYSTEM 14

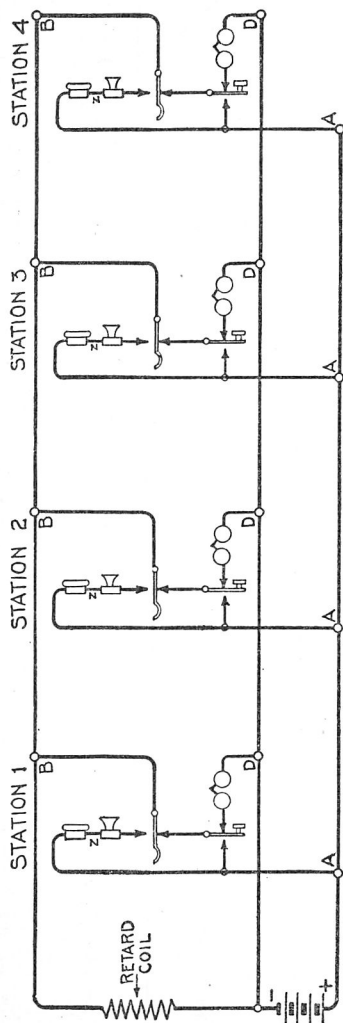
DOTTED LINES DENOTES METHOD
OF CONNECTING STRAP WIRES

Figs. 7,584 to 7,588.—Schematic diagrams of Graybar two station private line inter-phone system; 7,584, wall type; 7,585, hand set, surface box type; 7,586, hand set, desk stand; 7,587, hand set, flush box type.



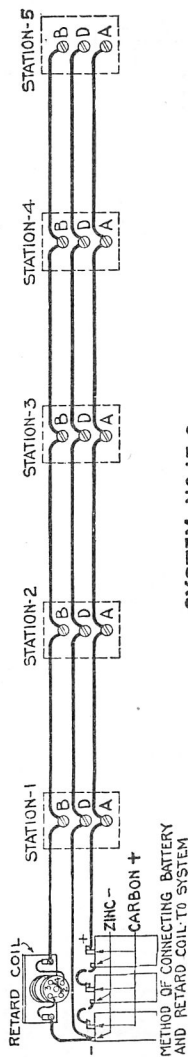
SYSTEM NO. 14

Fig. 7,589.—Diagram of connections of Graybar two station private line inter-phone system.



SCHEMATIC WIRING DIAGRAM - SYSTEM NO. 15-C

FIG. 7,590.—Wiring diagram of Graybar code ringing, common talking inter-phone system.



SYSTEM NO. 15-C

FIG. 7,591.—Diagram of connections of Graybar code ringing, common talking inter-phone system.

5. Master station; common talking.

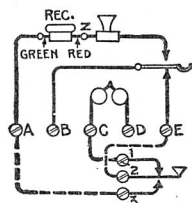
6. Master annunciator.

7. Master annunciator; common talking.

Two Station Private Line.—This system is for a small installation where the sets are distantly located from each other. Only two wires are used for connecting the inter-phones, dry cells being required at each station.

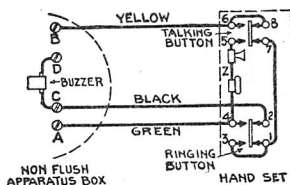
In operation, either station can ring the other by simply depressing the push button of the set. Wall, desk, or hand set inter-phones may be used interchangeably.

A battery of three dry cells is required at each station to furnish current for talking and ringing if the length of line be less than 750 feet. If the

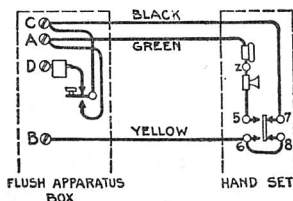


SCHEMATIC OF
NO'S 1527-C-1 & 1539-C-1
SYSTEM 15-C

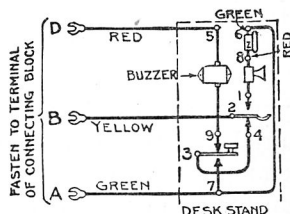
DOTTED LINES DENOTE METHOD
OF CONNECTING STRAP WIRES
FURNISHED WITH EACH SET
(SEE LAST PAGES FOR INSTALLING)



SCHEMATIC OF
NO. 6043-P SYSTEMS 14 & 15-C



SCHEMATIC OF
NO'S 6042-AE & AF SYSTEMS 14 & 15-C

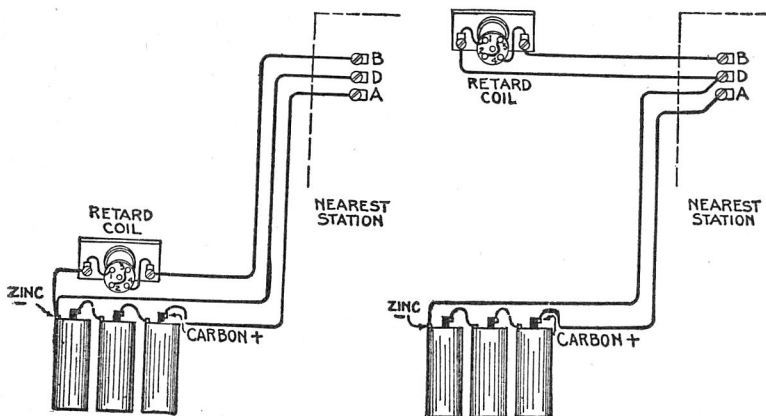


SCHEMATIC OF
NO. 6034-BE SYSTEM-14 & 15-C

FIGS. 7,592 TO 7,595—Schematic diagrams of Graybar code ringing, common talking inter-phone system.

length of line be increased, additional dry cells are required at each station to insure satisfactory ringing.

Code Ringing: Common Talking System.—This is a simple and inexpensive system for small residences, warehouses, stores



FIGS. 7,596 and 7,597.—Method of connecting battery for Graybar code ringing, common talking inter-phone system. A retardation coil is required for this system. This coil is mounted on a small wood block and provided with two terminals. The function of the retardation coil in this system is to prevent the talking current being shunted through the battery while a conversation is being carried on. Only one battery is required to furnish current for talking and ringing. Do not use more than five Blue Bell dry cells connected in series. The retardation coil must be mounted close to the battery or at a point between the battery and the nearest station. The connections should be made as shown in fig. 7,596. Three wires should be run from the battery and coil to the nearest station as shown. In case the coil is to be mounted close to the nearest station, the connections should be made as shown in fig. 7,597.

or mercantile establishments, where only a few stations are required and the number of calls between the stations is not frequent. Requires only three line wires throughout the system for two or more stations. Only one conversation can be carried on at a time.

Each station is equipped with a push button. In operation, when the push button is depressed the bells at all the other stations ring.

If more than six stations be in service, signaling code mistakes are likely to occur, due to the possibility of misunderstood signals.

Where the initial installation comprises more than four or six stations the selective ringing common talking system should be used.

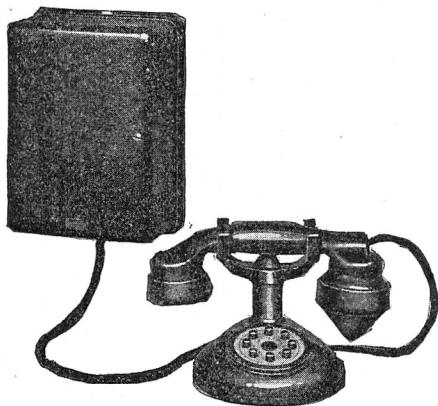
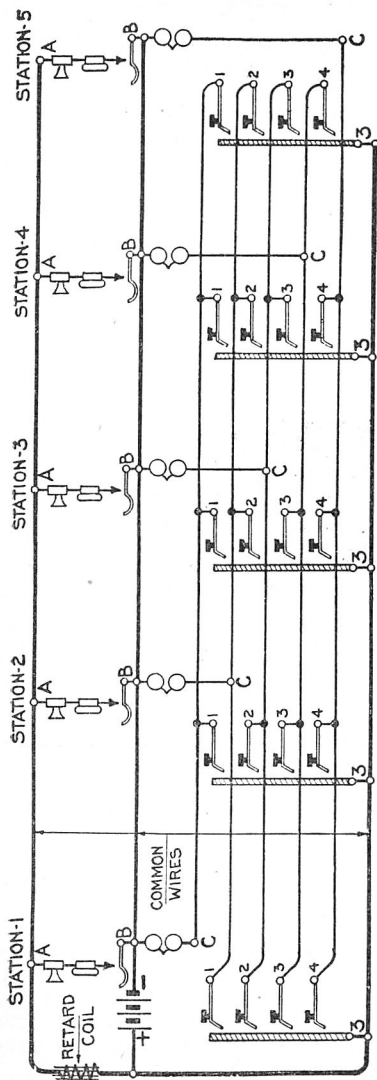


FIG. 7,598.—Graybar selective ringing common talking cradle type inter-phone system. *It consists of* a hand set with a cradle type mounting having push buttons mounted in the base. The hand set is black moulded bakelite. The interphone set includes an apparatus box containing a bell and a connecting block.

Selective Ringing: Common Talking System.—This system is adapted to multi-station installation where conversation can be limited to one at a time. Any station in the system can selectively ring another station.

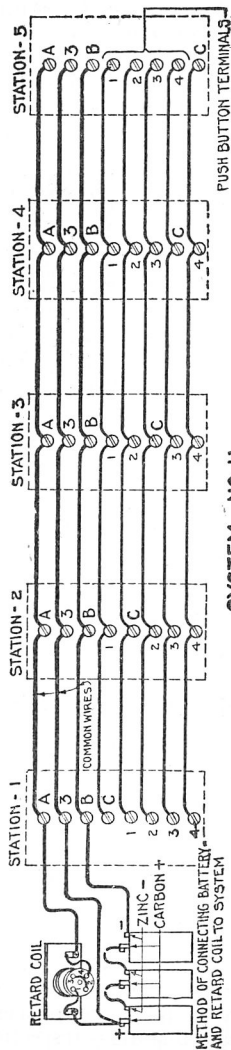
Each inter-phone in the system is equipped with a number of push buttons, one for each other station in the system.

In operation, by depressing the button marked with the name or number of the station wanted, the bell at that station only will ring. Wall type inter-phones for this system may be obtained in capacities of 2, 3, 4, 6 and 8 buttons, accommodating 3, 4, 5, 7 and 9 stations respectively; desk and hand set inter-phones in capacities of 4 and 8 buttons, accommodating 5 and 9 stations respectively.



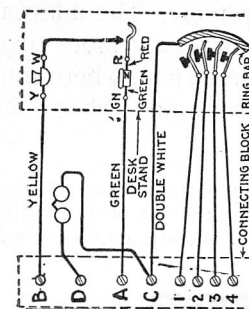
SCHEMATIC WIRING DIAGRAM - SYSTEM NO. II.

Fig. 7,599. — Wiring diagram of Graybar selective ringing, common talking inter-phone system.

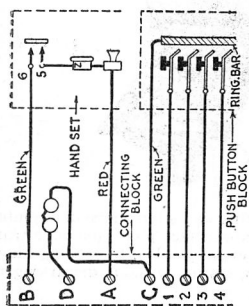


SYSTEM NO. II

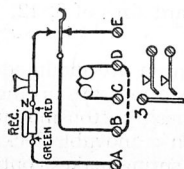
Fig. 7,600. — Diagram of connections of Graybar selective ringing, common talking inter-phone system.



SCHEMATIC OF
NO. 6034-M, P, B, J & BK SYSTEM II & I2

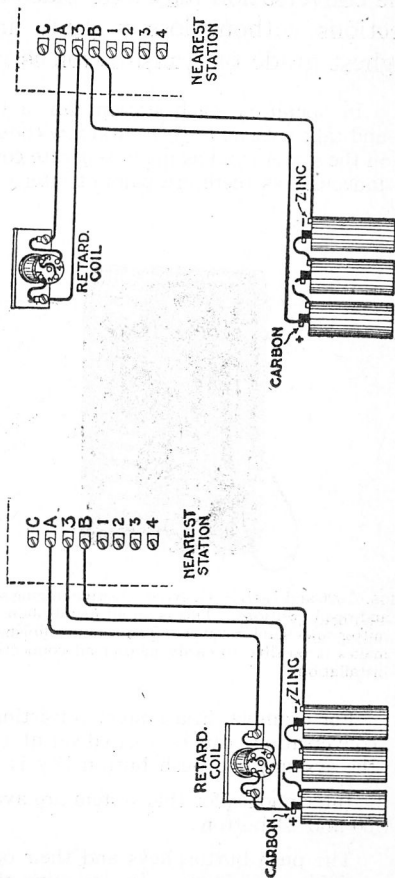


SCHEMATIC OF
NO. 6034-AZ, BB, BG & BH SYSTEM II & I2



SCHEMATIC OF
NO. 1527-C & 1539-C TYPES
SYSTEM II

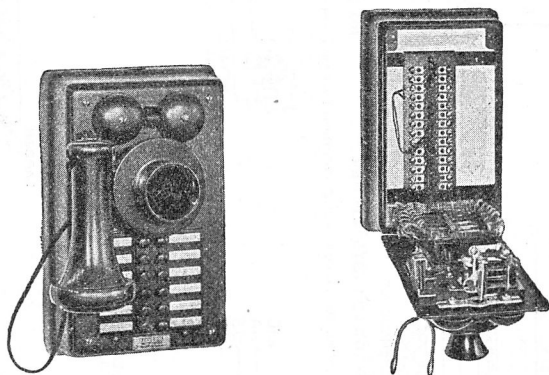
DOTTED LINES DENOTE METHOD
OF CONNECTING STRAP SET
FURNISHED WITH EACH SET
(SEE LAST PAGES FOR INSTALLING)



Figs. 7, 604 and 7, 605.—Method of connecting battery for Graybar selective ringing, common talking inter-phone system.

Selective Ringing: Selective Talking System.—The adaptation of this system is for service where frequently more than one conversation may take place at the same time, where connections without loss of time are necessary and where the highest grade of transmission is required.

In operation, each station can, by pressing button, selectively ring and talk with any other station without disturbing the rest of the stations in the system and as many separate conversations can be carried on simultaneously as there are pairs of inter-phones.



FIGS. 7,606 and 7,607.—Graybar selective ringing selective talking wall inter-phone in assembled and open positions. This is an all metal phone having a hinged face plate, movable transmitter and hand receiver. The sets are finished in black enamel. The face being hinged makes it possible to easily inspect all connections and apparatus, without disturbing the installation.

For example, in a system consisting of six inter-phones, three separate conversations can be carried on at the same time. For each station in the system, one push button key is required in each inter-phone.

Inter-phones for this system are available in standard sizes of 6, 12, 16, 20 and 24 buttons.

The push button keys and their operating mechanism are mounted in a rigid metal frame. In designing this key two operations are arranged for, as follows: Each key consists of a hard rubber push button mounted on a metal plunger, which passes through a hole in a movable locking plate. When the button is completely depressed the spring makes contact

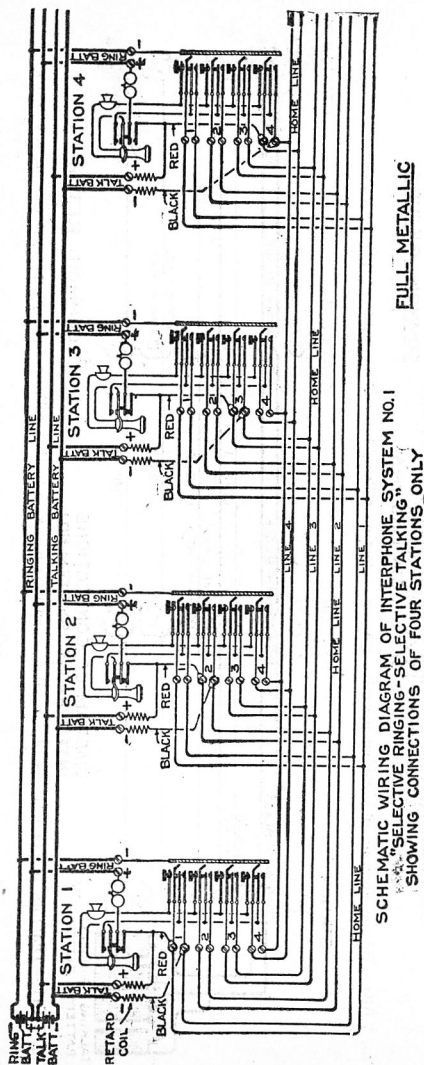


Fig. 7,608.—Wiring diagram of Graybar selective ringing, selective talking inter-phone system; full metallic.

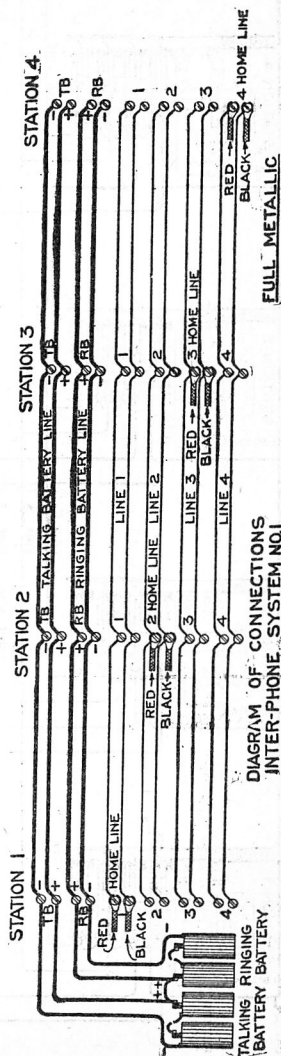


Fig. 7,609.—Diagram of connections of Graybar selective ringing, selective talking inter-phone system; full metallic.

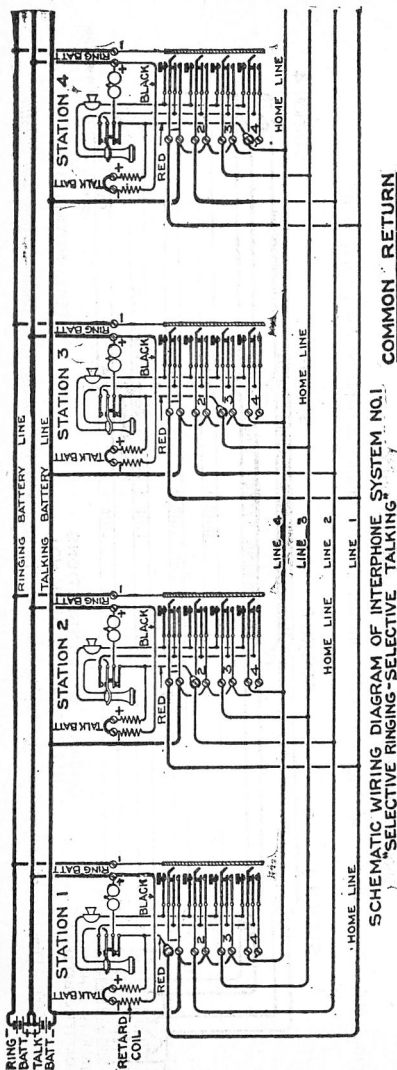


FIG. 7,610.—Wiring diagram of Graybar selective ringing, selective talking inter-phone system; common return.

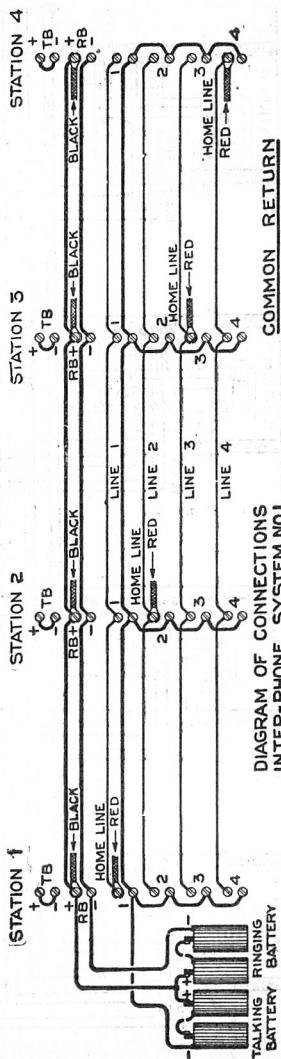
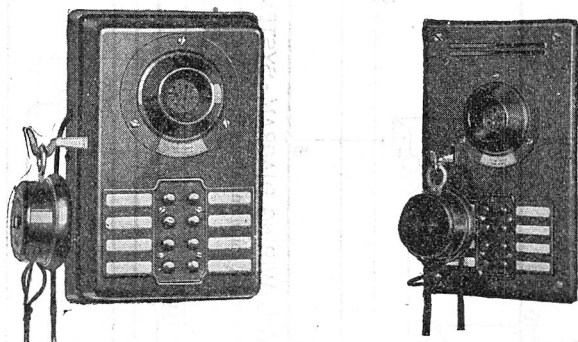


FIG. 7,611.—Diagram of connections of Graybar selective ringing, selective talking inter-phone system; common return.

with the ringing battery supply causing the ringing current to flow to the station to which this particular key is connected, and ringing the bell at that station.

When the pressure is released, the plunger returns to an intermediate position, breaking the ringing contact and placing the inter-phone on the line of the station called ready for conversation.

While the conversation is taking place, the plunger is automatically held in the talking position by the locking plate until the plate is actuated by depressing another button. The pressing of another button causes the locking plate to release the key so that it assumes its normal position. Talking current for the inter-phone is cut off as soon as the receiver is replaced on the switch hook.



FIGS. 7,612 and 7,613.—Graybar master station common talking inter-phone system; projecting and flush wall type sets.

Master Station: Common Talking System.—It consists of one centrally located master station inter-phone to which are connected other *outlying station* inter-phones. The system provides for communication from a central point to different stations and vice versa.

The outlying stations are equipped with only one button which will ring the master station when depressed. Only one conversation can be carried on at a time.

The master station inter-phone is equipped with a number of push buttons; one for each outlying station.

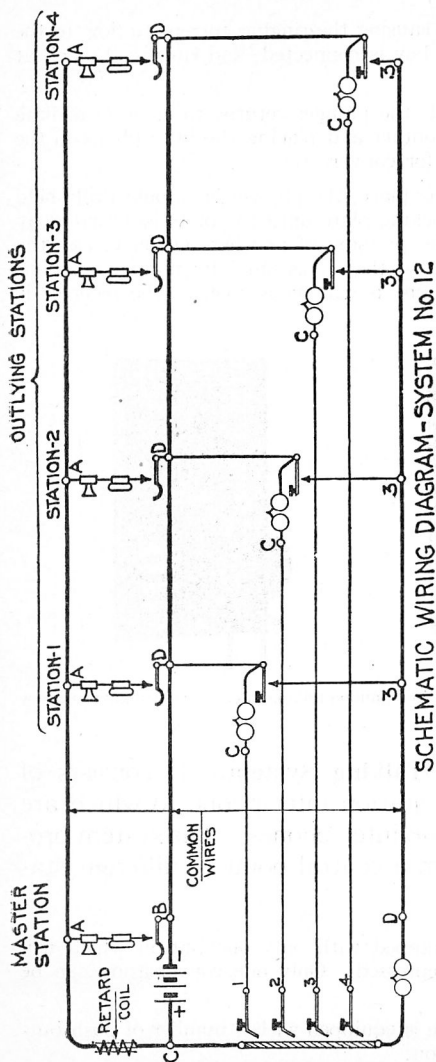


FIG. 7,614.—Wiring diagram of Graybar master station, common talking inter-telephone system.

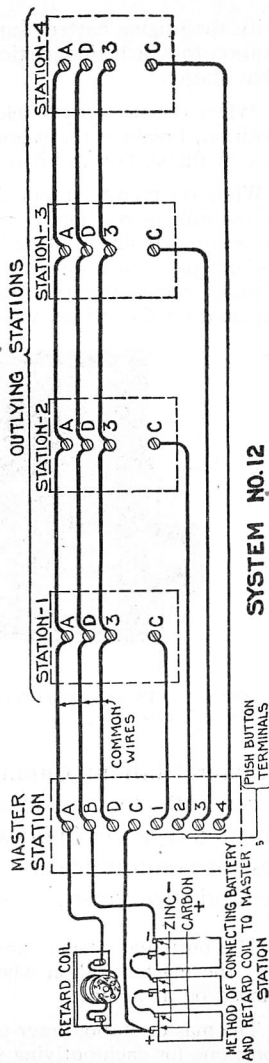
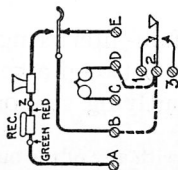
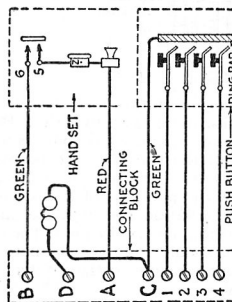


FIG. 7,615.—Diagram of connections of Graybar master station common talking inter-telephone system.



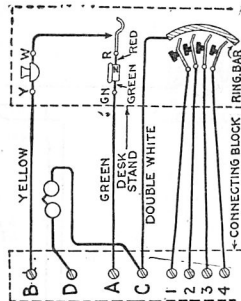
**SCHEMATIC OF
NO. 1527-C1 & 1539-C1
OUTLYING STATION
SYSTEM 12**

DOTTED LINES DENOTE METHOD
OF CONNECTING STRAP WIRES
FURNISHED WITH EACH SET
(SEE LAST PAGES FOR INSTALLING)



SCHEMATIC OF

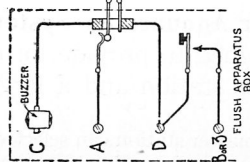
NO. 6034-AZ, BB, BG & BH SYSTEM 11&12 NO. 6034-M, P, BU & BK SYSTEM 11&12



SCHEMATIC OF

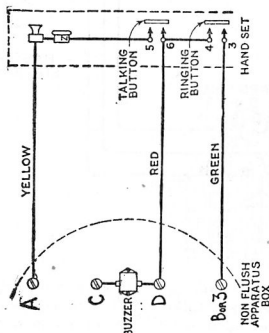
**SCHEMATIC OF
NO. 1527-C & 1539-C TYPES
MASTER STATION
SYSTEM 12**

DOTTED LINES DENOTE METHOD
OF CONNECTING STRAP WIRES
FURNISHED WITH EACH SET
(SEE LAST PAGES FOR INSTALLING)



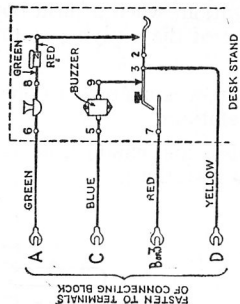
SCHEMATIC OF

NO. 6042 E&K OUTLYING STATIONS-SYSTEM 12



SCHEMATIC OF

NO. 6043-E OUTLYING STATION-SYSTEM 12



SCHEMATIC OF

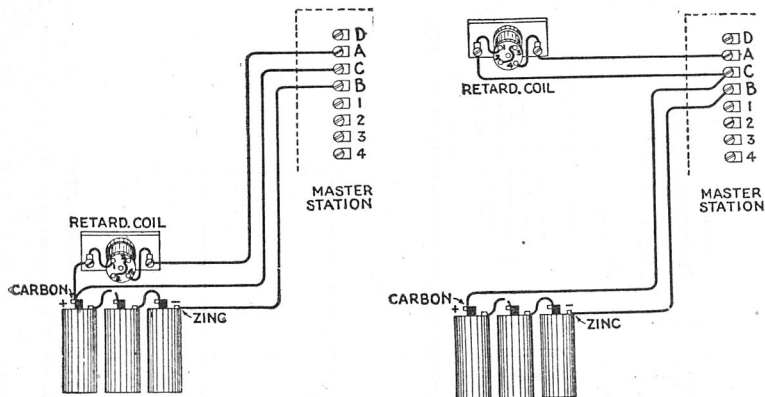
NO. 6034-AP OUTLYING STATION-SYSTEM 12.

Figs. 7,616 to 7,622.—Schematic diagrams of Graybar master station, common talking inter-phone system.

In operation, when a push button is depressed marked with the name or number of the outlying station wanted, the bell at that station only will ring.

The system is adapted to one master station and from two to sixteen outlying stations.

Wall, desk and hand set inter-phones may be used for either the master or outlying stations.



FIGS. 7,623 and 7,624.—Method of connecting battery to master station for Graybar master station common talking inter-phone system. Do not use more than five Blue Bell dry cells connected in series. When using wires of No. 22 B. & S. gauge (as contained in the standard inter-phone cables recommended for this system) the wire distance between the master and the farthest outlying station should not exceed 750 ft., as this is the longest distance over which satisfactory ringing can be secured with apparatus of this system and with battery and wires of the size outlined. The retardation coil may be mounted close to the battery or at a point between the battery and the master station. The connections should be made as shown in fig. 7,623. Three wires should run from the battery and coil to the master station. In case the coil is to be mounted close to the master station, the connections should be made as shown in fig. 7,624.

Master Annunciator System.—This is a non-interfering system designed to provide for communication between a central or master station and a large number of outlying stations.

The master station can selectively ring and talk with any of the outlying stations and the outlying stations can call the master station.

The master station annunciator consists of a number of drops and jacks one for each outlying station in the system, a push button for ringing, a hand set inter-phone and a cord and plug for calling and answering.

Each outlying station inter-phone is equipped with a push button for ringing the master station and at the same time operating one of the annunciator drops, thereby registering the call.

In operation: 1. To call an outlying station, the master station operator inserts the plug into the jack corresponding to the station wanted and depresses the ringing button of the

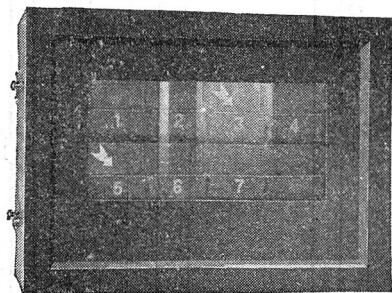
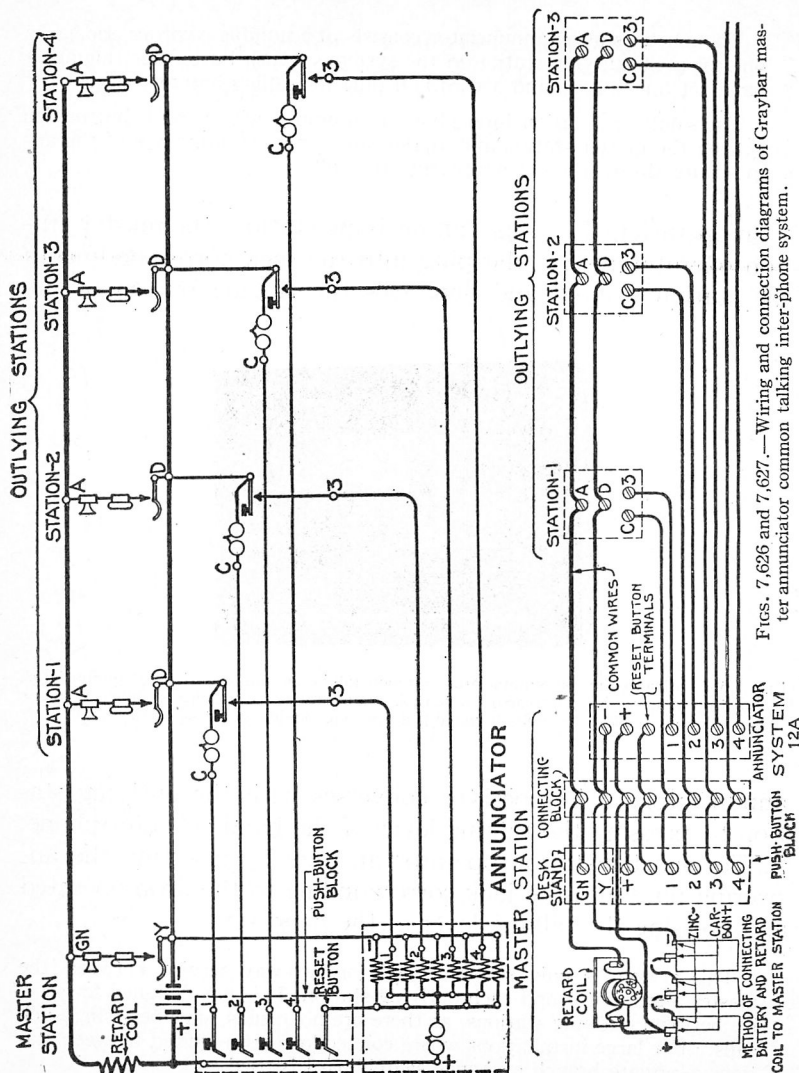


FIG. 7,625.—Graybar master annunciator, common talking system electric reset annunciator. The drop indicator is a white arrow which points directly at a white drop number; it can be seen from any angle. The audible signal is a new type double adjusting buzzer.

annunciator. The operator converses with the outlying station by pressing the talking lever of the hand set inter-phone; 2. The master station operator answers by inserting the answering plug into the jack corresponding to the drop operated and pressing the talking lever of the hand set.

This system is only recommended for two-way service between the master annunciator and each outlying station. It is not designed for service between outlying stations, as there are no means of supervising such calls. For large installations where connections are required between stations a private branch exchange switchboard is used.

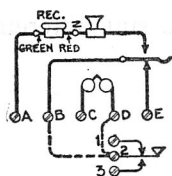


FIGS. 7,626 and 7,627.—Wiring and connection diagrams of Graybar master annunciator common talking inter-phone system.

ANNUNCIATOR
PUSH-BUTTON BLOCK
SYSTEM
12A

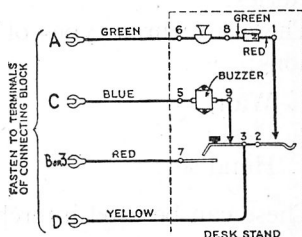
Master Annunciator: Common Talking System.—This system meets the requirements of school service. The system consists of an annunciator for use in the principal's office for registering the calls from the class rooms, also a desk stand and a push button block for calling each class room inter-phone.

The principal's or master station equipment consists of an electric reset annunciator and a push button block with one drop and button for

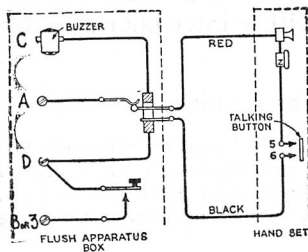


SCHEMATIC OF
No. 1527-C-1 & 1539-C-1
OUTLYING STATION
SYSTEM 12-A

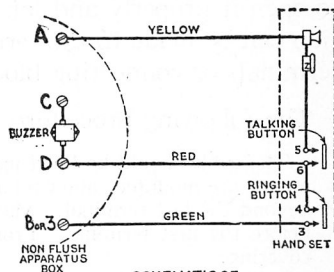
DOTTED LINES DENOTE METHOD
OF CONNECTING STRAP WIRES
FURNISHED WITH EACH SET
(SEE LAST PAGES FOR INSTALLING)



SCHEMATIC OF
NO. 6034-AP OUTLYING STATION-SYSTEM 12



SCHEMATIC OF
NO. 6042 E & K OUTLYING STATIONS-SYSTEM 12



SCHEMATIC OF
NO. 6043-E OUTLYING STATION-SYSTEM 12

FIGS. 7,628 to 7,631.—Schematic diagrams of Graybar master annunciator common talking interphone system.

each class room station in the system. The push button block also contains buttons for electrically resetting the operated drops. The principal is signaled from the class room set by means of the push button on each set.

Inter-phone Apparatus.—Inter-phone systems are simple and consist essentially of the following equipment:

1. Inter-phones;
2. Batteries to furnish current for ringing and talking;
3. Wire or cable to connect inter-phones and batteries;
4. Installing material (usually furnished by the installer) for connecting and fastening inter-phones, cable (or wire) and batteries.

There are three types of inter-phones to suit different conditions:

1. Wall;
2. Desk;
3. Hand set.

These can be used interchangeably in the same system.

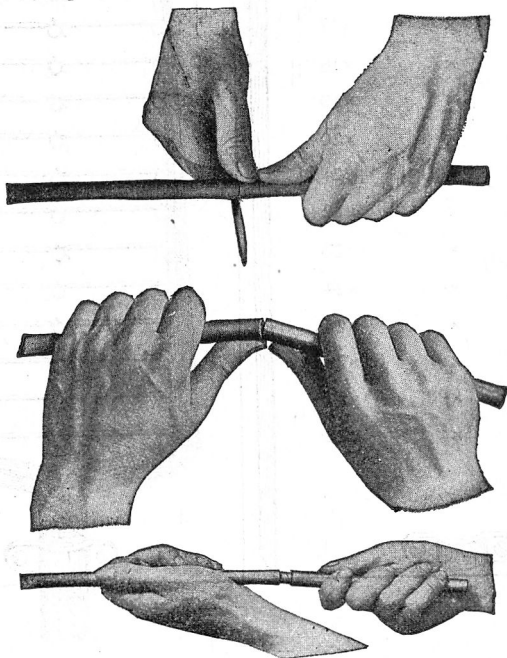
Preparing Inter-phone Cable for Connections.—After having definitely established the route of the cable, it will be necessary to open it properly and fan out the cable wires before connection can be made to the terminals of either inter-phones, cable terminals or connecting blocks.

The following procedure will serve as a guide:

The cable should be lined up parallel with the board on which the terminals are mounted, allowing a length of 4 to 6 inches of cable to extend beyond the last terminal. Mark the cable at a point about $1\frac{1}{2}$ to 2 ins. before the first terminal. From this mark to the end remove the cable covering.

If the cable have a lead sheath, the latter can be removed as shown in figs. 7,632 to 7,634. If it have a braided covering, the latter can be removed by making a slit by means of a sharp penknife, lengthwise from the end of the cable to the marked point.

Avoid cutting the insulation of the conductors. After this cut has been made, the braiding can be peeled off easily, and removed with a pair of cutters. A wrapping of lacing twine should then be made around the cable where the braiding ends to prevent any further loosening of the insulation at that point.



FIGS. 7,632 to 7,634.—Method of preparing inter-phone cable. First make a very slight cut around the cable as in fig. 7,632 about one third through the lead. The lead sheath can then be easily broken off at this point by bending it backward and forward, as in fig. 7,633, after which it can easily be pulled free of the cable, as in fig. 7,634. In cold weather or if the cable has been bent or twisted the sheath may not come off easily. In that case, heat the end to be pulled off with a candle. This will soften the wax inside the cable and allow the lead sheath to be removed easily.

After the covering has been removed from the cable, the wires should be formed, fanned out and sewed up so that they will have the proper shape for connecting to the terminals. This is best done by the aid of a small wooden board as in fig. 7,635.

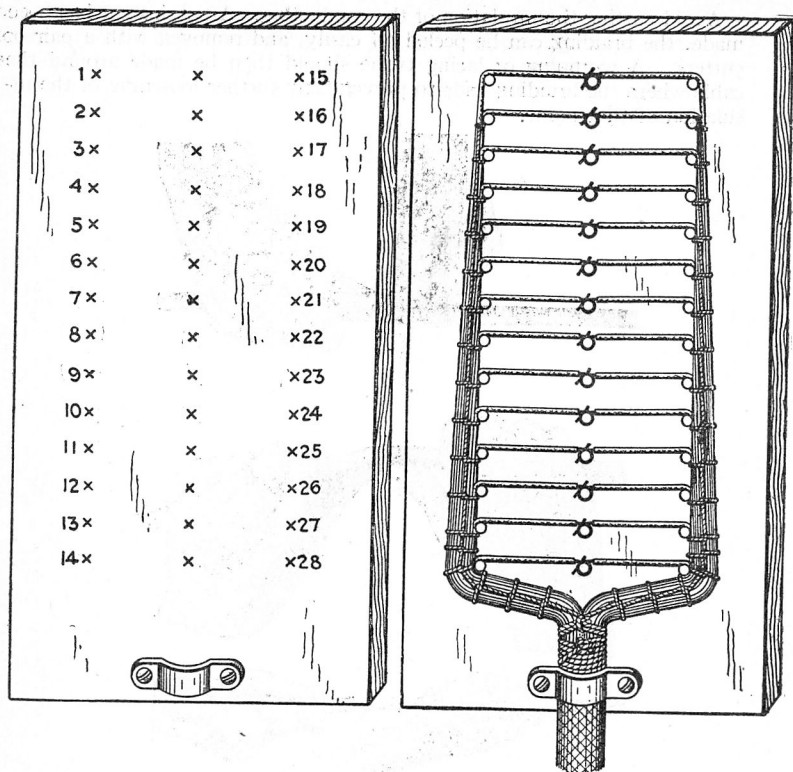


FIG. 7,635.—Board template for *fanning* and *sewing* inter-phone cable. The marking of the board depends entirely upon the location of the terminals to which the wires are to be connected. For example, the following describes a cable forming board for 24 button inter-phones of a two station line. Mark the board as shown each outside X mark being made at a point where a wire is to be brought to a terminal and a center X mark in the line between them. The vertical distance between the X marks will be the same as between the terminals of the apparatus. The horizontal distance between the outside X marks will be determined by the size of the block on which the terminals are mounted. Small nails are now driven in the X marks, and the end of the cable laid out flat on the board against these nails. The wires are then brought out from the cable in the order in which they should run to the terminals and twisted around the center nails as in fig. 7,636.

FIG. 7,636.—Board template with spacing nails showing inter-phone cable *fanned* and *sewed*. The lacing twine is stitched around the cable as shown in fig. 7,637.

After the cable has been prepared as shown in the illustrations the conductors should now be cut off at a point about 1 in. beyond that required to reach the terminals when the cable is in its final position. The insulation of each wire should then be removed to about 1 in. from the end. This is usually done by squeezing the insulation with a pair of flat nose pliers. If sufficient pressure be applied the insulation can then be torn off easily. Do not use a knife for cutting the insulation. A knife may nick the wire, later resulting in a break and causing trouble.

After the insulation has been removed the cable should be taken off the forming board and connected to the terminals. It is advisable to shellac the formed portion of the cable with transparent shellac, which will prevent the insulation fraying. Care should be taken to remove any piece of wire which may have fallen in among the terminals while wiring. This is often a source of trouble if not done. Every screw and lock nut should also be examined to insure tight and positive connections.

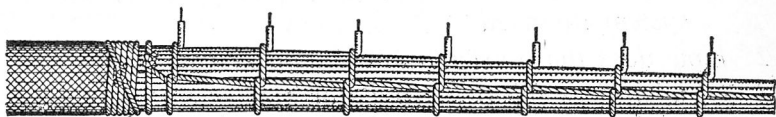


FIG. 7,637.—Detail of inter-phone cable showing lacing twine stitched around the cable to hold the wires permanently in position. Another method to secure the same result consists of drilling small holes, about $\frac{1}{4}$ in. diameter, through the board at the outside X marks, fig. 7,635, and pushing the proper wires through these holes and then stitching the cable with lacing twine as explained before.

TEST QUESTIONS

1. *What is an inter-communicating telephone?*
2. *How does an inter-phone system work?*
3. *Name the different inter-phone systems in general use.*
4. *Describe a two station private line.*
5. *Explain the operation of the code ringing common talking system.*

6. *How does the selective ringing common talking system work?*
7. *What is the adaptation of the selective ringing selective talking system?*
8. *Draw a diagram of the selective ringing, selective talking system.*
9. *Explain the operation of the master station common talking system.*
10. *Draw a diagram of the master station common talking system.*
11. *For what service is the master station annunciator system intended?*
12. *How does the master annunciator system work?*
13. *Of what does the principal's or master station school equipment consist?*
14. *Describe the various apparatus used in inter-phone systems.*
15. *How is inter-phone cable prepared for connecting?*
16. *Describe the construction of a board template for fanning and sewing.*

CHAPTER 187

Telephone Troubles

Subscriber Line Troubles.—1. Bell does not ring; may be caused by

- a.* open bell;
- b.* open condenser;
- c.* open bell strap wire;
- d.* bell out of adjustment;
- e.* biasing spring too tightly drawn.

2. Can't hear; may be caused by

- a.* open receiver magnet;
- b.* open receiver cord;
- c.* short-circuited receiver;
- d.* short circuited receiver cord;
- e.* open secondary coil;
- f.* open switch hook contact;
- g.* receiver diaphragm missing;
- h.* receiver diaphragm bent.

3. Can't talk; may be caused by

- a.* open primary coil;

- b.* open switch hook contact;
- c.* open transmitter;
- d.* open transmitter cord;
- e.* short circuited transmitter;
- f.* carbon granules in transmitter *packed*.

4. Poor transmission; may be caused by

- a.* leakage in telephone line;
- b.* high resistance open in line;
- c.* short circuited induction coil;
- d.* partial short circuit in line;
- e.* partially demagnetized receiver.

5. Noisy connection; may be caused by

- a.* loose connection along the talking circuit;
- b.* line crossed with another line;
- c.* cross connection wire in Central office distributing frame;
- d.* defective heat coils;
- e.* defective jack at A board or B board;
- f.* defective cord connected to the line jack in the central office.

6. Can hear conversation of another circuit

- a.* lines crossed in cable terminal box;
- b.* breakdown in cable;
- c.* lines crossed at the distributing frame in the central office;
- d.* listening keys crossed on the A board.

7. Can't signal Central office operator

- a.* open line, one wire or both;
- b.* open transmitter circuit;
- c.* heat coil on central office distributing frame defective or missing;
- d.* line relay does not operate in central office;
- e.* dirty contacts in line relay in central office;
- f.* line lamp burned out on A board.

Central Office Troubles—A Board.—1. Operator can't hear on all connections

- a.* operator's telephone set defective;
- b.* operator's telephone circuit open or short circuited;
- c.* defective plug or cord.

2. No line lamps light

- a.* fuse blown in terminal room;
- b.* open strap wire at lamp sockets in A board jack panel.

3. No supervisory lamp on cords

- a.* fuse blown;
- b.* cord lamps burned out;
- c.* supervisory relay in cord circuit stuck up.

4. Position crossed (operator hears conversation with keys normal)

- a.* listening keys crossed.

5. Can't ring (on part of the cord circuits)

- a. ringing strap broken or disconnected.

6. Can't ring (on one cord only)

- a. ringing strap open at ringing key;
- b. defective contacts at ringing key.

7. Operator can't hear on one cord

- a. listening strap open at talking key;
- b. defective contacts at talking key.

8. A position crossed with a distant Central Office B operator

- a. call circuit button contacts crossed;
- b. call circuit button stuck down.

9. Line lamp is not extinguished after inserting the answering cord into the answering jack

- a. cut off relay does not operate;
- b. line relay does not release.

10. A operator can't get distant B operator over call circuit

- a. call circuit open at key;
- b. call circuit open at punchings;
- c. call circuit button springs not working.

Central Office Troubles—B Board.—1. No busy back on entire B board

- a.* lead open at beginning of line up;
- b.* lead open at power board.

2. B operator can't hear

- a.* defective telephone set;
- b.* open in telephone circuit;
- c.* open wire at grouping keys.

3. Steady guard lamp on a trunk cord

- a.* grounded tip side of trunk line;
- b.* defective (operated) relay in trunk circuit;
- c.* tip side of trunk crossed with another crossed cord at plug.

4. Steady guard lamp on a trunk while conversation is in progress

- a.* sleeve relay did not operate;
- b.* guard lamp relay remained operated;
- c.* sleeve of trunk cord open;
- d.* subscribers multiple jack sleeve open.

5. No guard lamp (on incoming call)

- a.* lamp burned out;
- b.* fuse blown;
- c.* lamp twisted in socket;

- d.* trunk wires open;
- e.* relay in trunk circuit does not operate;
- f.* dirty contacts in relay of trunk circuit
- g.* open contacts at sleeve relay.

6. No disconnect lamp on trunk

- a.* supervisory relay stuck up;
- b.* defective lamp.

7. No busy test

- a.* tip side of cord open;
- b.* sleeve relay contacts dirty;
- c.* sleeve relay operated.

CHAPTER 188

The Dial Telephone

(Automatic)

A dial telephone system is somewhat different from the manual system in-so-far as the equipment is concerned, although the desired function of connecting telephone subscribers together to satisfactorily carry on a conversation is exactly the same.

In a dial central office there is considerably more equipment, a great portion of which is automatically operated and controlled, more maintenance men and less girl operators.

In a dial telephone system all calls within a specified "local" area are handled exclusively by automatic switching apparatus, there being no operators required as in the manual system. Calls to more distant points, however, are routed through a special "A" operator who, besides taking care of the connection, makes out a ticket for a "toll" charge against the calling subscriber. The special "A" board is also employed for emergency connections and assistance calls from the subscribers in the same central office area. Besides the special "A" operators, in a dial central office, there are a number of girl operators working at "cordless" B-positions.

There are two distinct types of dial systems, namely:

1. Panel.

Used for large capacity central offices in big cities.

2. Step-by-step.

Used for small central offices.

Panel Dial System.—This system derives its name from the design of the multiple banks which are arranged as *panels* and which are mounted on frames known as *selector frames*.

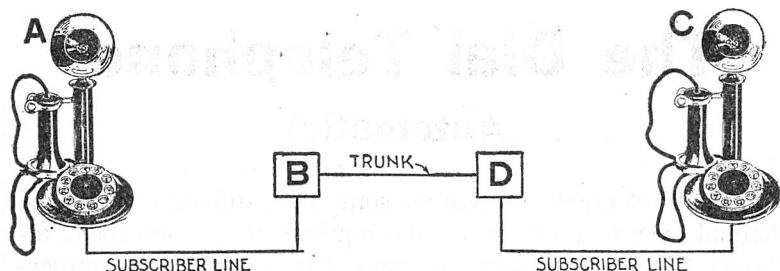
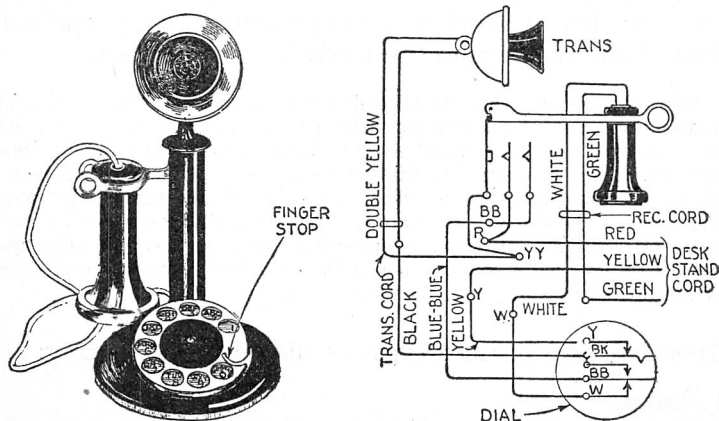


FIG. 7,628.—Simplified dial telephone system. A, telephone subscriber with number ATLantic 2357; B, Atlantic central office; D, Mayflower central office; C, telephone subscriber with number MAYflower 7348.



FIGS. 7,629 and 7,630.—Telephone with dial and circuit diagram.

Consider a telephone subscriber at location A connected to a dial Central Office at B and a second telephone subscriber at C connected to a second dial Central Office at D as indicated in fig. 7,628.

The telephone station at A consists of the familiar transmitter and receiver with the bell box. In addition there is a dial mounted on the transmitter stand as shown in fig. 7,629, all wired as in fig. 7,630. The telephone station at C is equipped the same as the one at A.

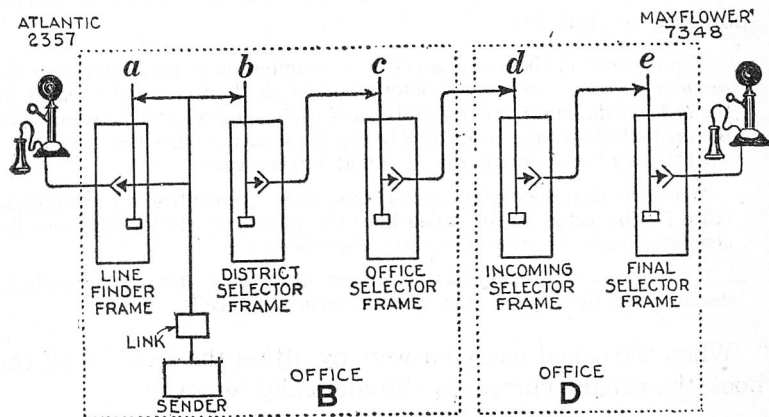


FIG. 7,631.—Panel dial system—routing of a call. a, line finder; b, district selector; c, office selector; d, incoming selector; e, final selector.

In operation: Subscriber A wishing to call C lifts the receiver off the hook and hears the dial tone, which is a sort of subdued and continuous br-r-r-r-r, sent by the *sender* at Central Office B. This means that he may proceed with the next operation, which in this case is to dial M-A-Y 7-3-4-8. By this operation the letters and the numbers are converted into different *pulses* which are received by the above mentioned sender at Central Office B where the seven different sets of pulses are *absorbed* by the sender, causing it to assume certain settings, which will direct and control the operation of various selector switches, some of which are located in Central Office B and some in the distant Central Office D, as indicated in fig. 7,631.

The sender in Central Office B, does not require that all the numbers be dialed before it can function. As soon as the three letters M-A-Y, known as the "*Central Office code*" letters have been dialed, the sender causes a so-called *district selector*, mounted on the district selector frame to operate and to move upward to find an idle trunk to another frame in the same office B which is known as the *office selector frame* and causes an idle selector on this frame to move upward and to stop at a set of terminals to which are connected wires, or *trunks*, coming from the distant office D.

When the numbers 7-3-4-8 are dialed the same sender in office B causes two different selectors in the distant office D to move upward and to locate the set of terminals corresponding to that line.

The first one of these two selectors is mounted on a frame known as the *incoming selector frame* and is determined by the first two digits dialed (in the order of dialing) namely 7 and 3, and the second selector is mounted on the final selector frame and is directed by the sender in office B in accordance with the last two numerals dialed, 4 and 8 in this case.

When the final selector in office D has, under the control of the sender in office B, connected to the called line, the incoming selector furnishes the generator current to ring the called subscriber's bell.

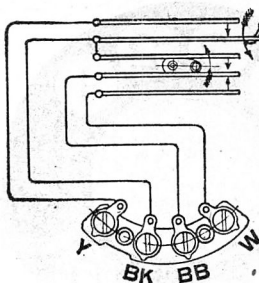
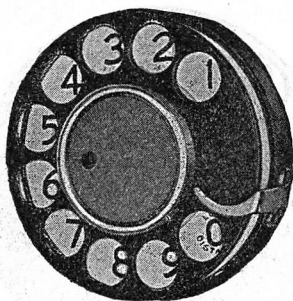
By this time the sender has performed all its work and it is accordingly disconnected from the district selector circuit of office B.

When the called party answers by lifting the receiver off the hook the ringing current is automatically removed.

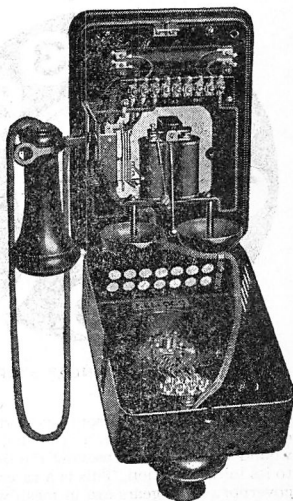
The conversation takes place and eventually it is finished and the parties hang up the telephone receivers, causing all the selectors to disconnect automatically.

The apparatus will now be described, stripped of all the circuit complications and the intricate mechanical details.

The Dial.—As shown in the accompanying illustrations, the dial is generally mounted on the telephone. It is a device consisting of a rotating disc (finger wheel), with a spring and a cam lever.



FIGS. 7,632 and 7,633.—Assembled dial and wiring diagram.



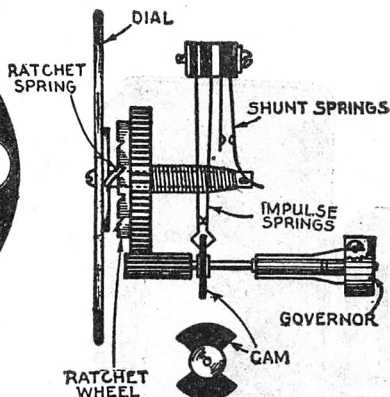
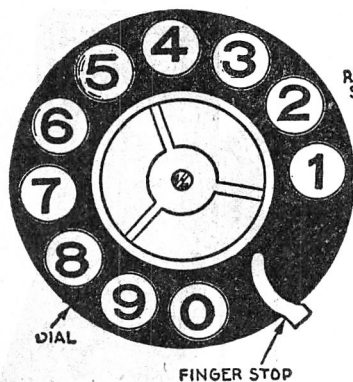
FIGS. 7,634 and 7,635.—Kellogg common battery telephone; enclosed gong wall type arranged for automatic dial. Fig. 7,635 open view showing interior construction.



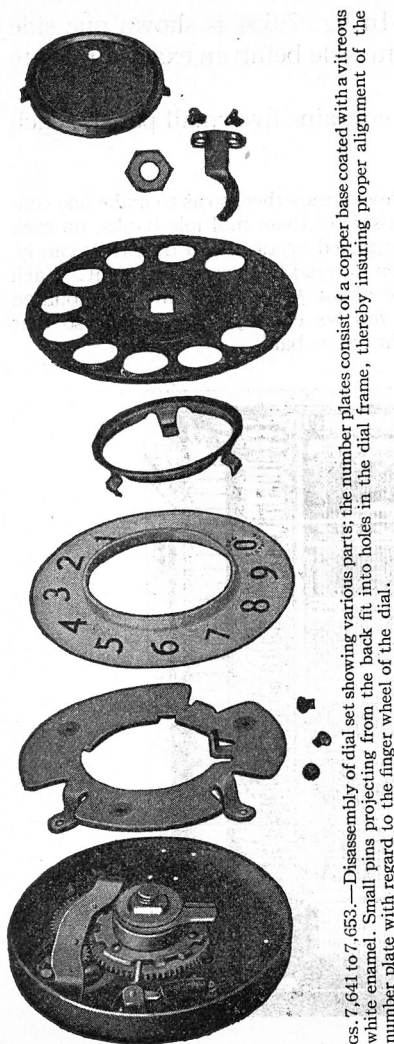
FIG. 7,636.—Single central station stops.



FIG. 7,637.—Multi-central station dial showing central station letters, and numerals.



FIGS. 7,638 to 7,640.—Front and side view of dial, showing the mechanism and end view of cam. *In operation*, as the dial is rotated by the finger clockwise, a coiled spring is wound which, after removing the finger on reaching the *finger stop* causes the dial to return to its initial position. This is a ratchet which transmits the return movement to gears and a governor. The gears are in mesh with a pinion on which is a cam which is so geared that when say No. 1 is "dialed" the cam will make one half revolution, opening the impulse spring once. Similarly the impulse spring will be opened a number of times corresponding to the number dialed.



Figs. 7,641 to 7,653.—Disassembly of dial set showing various parts; the number plates consist of a copper base coated with a vitreous white enamel. Small pins projecting from the back fit into holes in the dial frame, thereby insuring proper alignment of the number plate with regard to the finger wheel of the dial.

When a number is dialed the finger wheel is pulled around to the finger stop, and then let go. The spring now pulls the finger wheel back to its original position and in doing so the cam, which is attached to the finger wheel, causes a set of springs to separate and to come together successively opening and closing the circuit of the line, thereby generating *pulses*.

The number of pulses generated is equal to the figure under the hole into which the finger is placed. The return speed of the finger wheel is controlled by a *governor* so that when "O" is dialed the finger wheel will return to normal in one second, or 10 pulses are generated in one second.

In larger cities the plate under the holes bears certain letters of the alphabet in addition to the numbers. These letters are used for dialing the first three letters of the central office names. Figs. 7,636 and 7,637 show comparison of the single office dial and the multi office dial.

Selector Frame; Selectors.—In fig. 7,654 is shown one side of one selector frame, the opposite side being an exact duplicate of the one shown.

The framework is of iron and contains five small panels, each called *multiple banks*.

These five banks are lined up one above the other, so as to make one continuous vertical plane. Facing each side of these multiple banks, on each side of the frame, are 30 selectors arranged vertically so that they can be elevated to the highest point and then lowered to the starting point. Each selector consists of a long brass tube about $\frac{1}{4}$ in. in diameter, mounted vertically and holding *five multiple brushes* equally spaced apart so that each brush can reach the entire height of one bank.

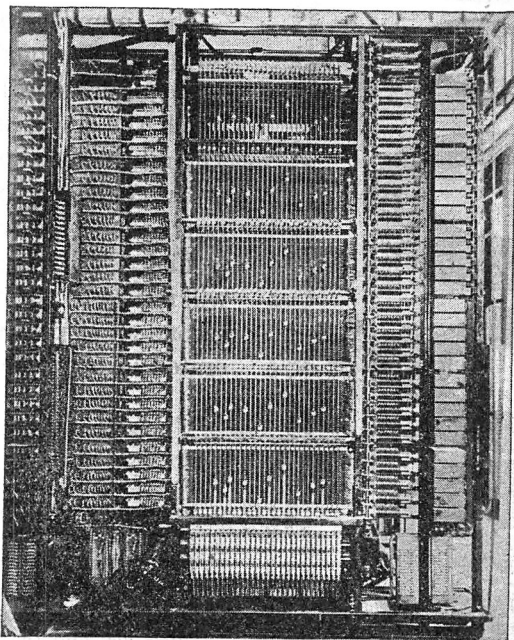


FIG. 7,654.—Panel type selector frame.

At the upper end of the selector rod is mounted a set of *commutator brushes* and at the lower end is attached a *rack* which is a flat strip of bronze with rectangular perforations, as shown in figs. 7,655 to 7,657.

Each multiple bank is built up of 300 individual brass strips running the entire length of the bank, each separated by an insulated strip. The brass strips have 30 projections on each edge so that when the whole assembly is bolted up there are formed on each side of the bank 30 sets of projections, each set composed of three vertical rows and each vertical row containing 100 terminals.

Each set of three terminals serves for one line or one trunk and is used for tip T, sleeve S, ring R (see fig. 7,661) so that there are 100 lines or trunks

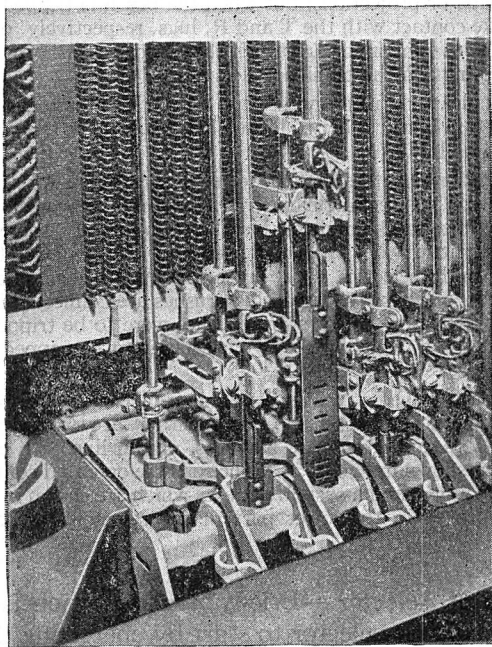


FIG. 7,655.—Lower portion of selector frame showing raised rack attached to lower end of selector rod. The rack is made of spring bronze and has 100 rectangular perforations spaced vertically corresponding to the 100 trunks (vertical) on the bank, and five rectangular perforations wider apart corresponding to tripping positions of the selector brushes. The bottom multiple brush is shown making contact with a set of terminals in the bottom bank.

arranged in a vertical column, and each line appearing 30 times on one side of the bank and 30 times on the other side.

The selectors are arranged so that there is one in front of each vertical column, and so that a particular brush of that selector can be stopped at any one of the 100 lines to make contact with the T, S, and R, projections on the multiple bank corresponding to that line.

The brush has four parallel contact springs so arranged that normally while the brush is untripped the contact springs do not touch the multiple bank contacts, or projections; but when the brush is tripped the two outer springs make contact with the T and R, lugs, respectively, on the multiple bank and the two inner springs touch the S, projection. Actually then the two inner springs on the brush serve as one.

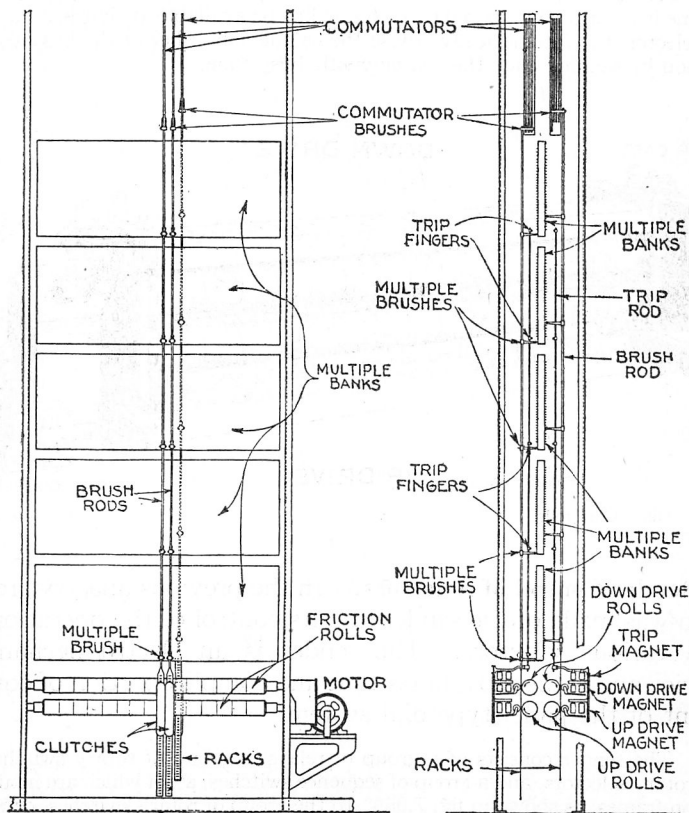
The commutator brushes at the top of the selector rod slide over brass bars moulded in hard rubber to form what is known as a *commutator* shown in fig. 7,656 and 7,657.

It was mentioned before that the lower part of the selector rod is attached to a rack which has rectangular perforations equally spaced to correspond with the 100 lines on the multiple bank, and in addition there are five other perforations a little wider apart and used in connection with the tripping of the brushes on the selector. Only one of the five brushes is tripped to make connection at one time, since all five brushes are connected in parallel and would cause a *cross* if two or more brushes were to be tripped together on one selector. As to which of the five brushes is to be tripped is determined by the sender.

The *rack* is arranged so that on one side it faces two cork rolls, revolving in opposite directions, and on the other side there are two magnetic clutches, named, *up-drive* and *down-drive* magnets, one in line with each revolving cork roller, as shown in fig. 7,656. The rolls are operated continuously by a small electric motor and a system of gears which are shown in fig. 7,658 and which are located in the lower part of the selector frame, as shown in fig. 7,656.

Operation of Selector.—Briefly, the operation is as follows: The sender causes a selector to start by energizing the up-drive magnet of the clutch which pushes the rack against the lower rotating cork roll, causing the rack to be raised. This in turn being attached to the selector rod pushes the selector upward.

As the selector rod continues in its upward movement it *reports*, so to say, back to the sender, by means of impulses from its commutator, how far upward it has progressed. When the selector rod has reached a certain height the sender immediately stops it to make arrangements to trip one of the five brushes. The brush to be tripped is the one that has to hunt in the bank where the trunk to the desired office, or where the desired line, is located. Then the selector is again started on its upward movement and



FIGS. 7,656 and 7,657.—Diagrams of assembly of selector frame and selector rods. Fig. 7,656, front view; fig. 7,657, end view.

the proper brush is tripped by a projection on the tripping rod which is rotated so that this projection gets in the way and snags the brush.

The selector continues to report to the sender through impulses received through its commutator as it moves upward to select the line, which is located in the bank where the brush has been tripped. When this line has been reached the sender stops the selector.

Provision is made that if the selector in question be hunting for an idle line in a certain group and no such idle line be available at that instant, the selector will automatically advise the calling subscriber of the busy condition by sending back the characteristic busy tone.

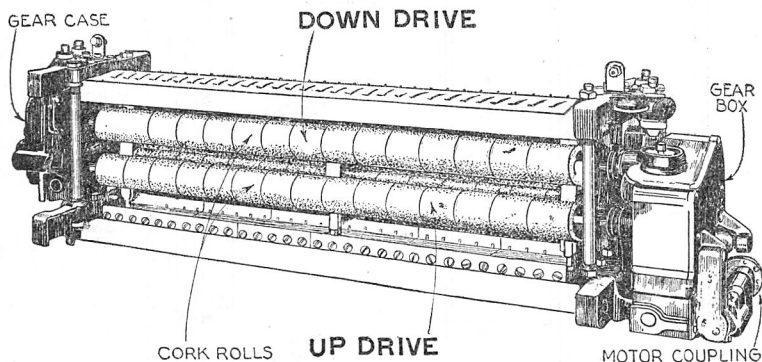


FIG. 7,653.—Cork rolls.

Sender Control of Selectors.—In the previous analysis, mention was made of the sender and its control of the operation of the various selectors. The sender is an electro-mechanical device and is the most important and complex portion of equipment of the panel type dial system.

The sender consists of a group of relays, a group of rotary switches or rotary selectors, and a group of sequence switches, all of which are mounted on frames, as shown in fig. 7,659. In the group of rotary switches, or *registers*, there is one switch for each letter and one for each digit dialed. Each one of these switches is constructed as shown in fig. 7,660 and is operated

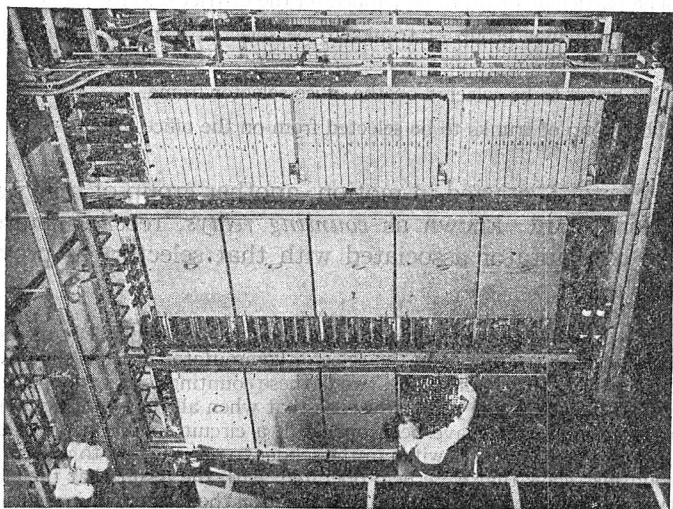
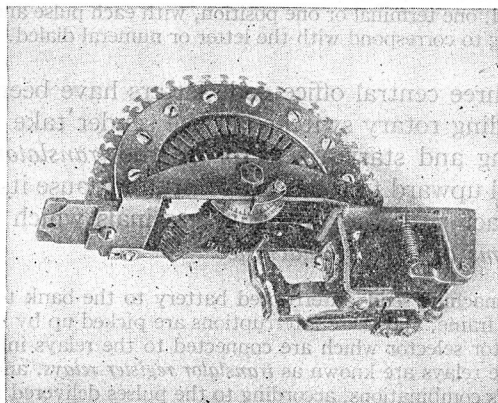


FIG. 7,659.—Group of senders on frame.

FIG. 7,660.—Rotary switch.

in accordance with the pulses sent over from the dial, that is, the rotor is stepped around, one terminal or one position, with each pulse and will take a certain *setting* to correspond with the letter or numeral dialed.

When the three central office code letters have been dialed, the corresponding rotary switches in the sender take their respective setting and start a selector on the *translator selector frame* to travel upward to a certain point, and cause its brushes to make contact with certain bank terminals which are connected to *drums* of a *pulse machine*.

This pulse machine sends interrupted battery to the bank terminals of the translator frame, and these interruptions are picked up by the brushes of the translator selector which are connected to the relays in the sender circuit. These relays are known as *translator register relays*, and are operated in various combinations, according to the pulses delivered to them by the pulse machine drums. However, the circuit combinations set up by these translator register relays will determine several conditions such as

1. Whether the central office dialed is a manual or a dial office.
2. The particular brush to be tripped on the district selector frame.
3. The particular group of trunks to be selected from on the district frame.
4. The brush to be selected on the office selector frame.
5. The group of trunks to be selected from on the office frame.

As a selector is started in motion, another group of relays in the sender circuit, known as *counting relays*, receives pulses from the commutator associated with that selector, as previously explained.

The number of counting relays to be introduced is dependent directly upon the register settings. As the selector commutator brushes slide over the brass bars on the commutator, two of these counting relays are operated every time a brass bar is passed over, so that when all the counting relays for a particular setting have been operated, a circuit condition is created which causes the sequence switch in the sender to operate and to release all the counting relays that were held operated, with the result that the electricity is disconnected from the clutch magnet on the selector frame causing

the selector rack to move away from the *up drive* roller. This of course means that the selector does not rise further. At this instant, the clutch pawl slips into the perforation of the rack and prevents the selector falling back to its starting position on account of its weight.

At this point, another circuit condition is created which causes the selector circuit sequence switch on the selector frame to operate and to place the selector circuit in the proper relation for the next operation, which is to cause the trip circuit to operate and the selector to start again on its upward travel.

This time one of the brushes on the selector is snagged and is brought in contact with the bank terminals. So far, the sender has accomplished what is known as *brush selection*. It is now necessary to bring that brush up to the first terminal of a desired group of trunks in that bank so that *trunk hunting* may be started.

The process of raising the selector to the first trunk of a desired group is known as *group selection* and is controlled likewise by counting relays under the control of another group of translator register relays in the manner just explained for brush selection.

When the selector has been raised to the first trunk of the desired group, *trunk hunting* takes place. This means that the selector brush makes a test on the sleeve of each trunk as it rises and every time it touches a busy trunk it receives energy to rise to the next trunk, until an idle trunk is found, when the energy to rise to the next trunk is not furnished, and the selector remains held up in that position by the pawl which slips into the rack perforation.

The operation of the sender, as outlined, applies to the control of the district selector as well as to the office selector in the home office.

The same sender directs the incoming selector and the final selector in the distant central office in a similar manner as above, except that the first two numbers dialed (the thousandths and hundredths) cause the associated registers in the sender to take certain settings and thereby throw in a certain number of counting relays to trip a particular brush on the incoming

selector, and to raise the incoming selector up to a certain group of trunks, so that it can pick out an idle trunk to the final frame.

The last two digits dialed (tens and units) cause the associated registers in the sender circuit to take certain settings and thereby introduce a certain number of counting relays to trip the desired brush on the final selector and to raise the selector to the particular terminal dialed.

The last function is accomplished at two speeds; the selector is brought at high speed up to within 10 terminals, and then the rack is driven upward at low speed up to the particular terminal desired. At this instant, the counting relays cause the selector to stop. The final selector remains up in that position as the result of the pawl having engaged the rack.

At this point the talking circuit for the calling party and the ringing circuit for the called party are completed and the sender is disconnected and released.

It was mentioned above that the final selector has two *up speeds*. This is accomplished by the use of two up drive cork rolls instead of one, and a clutch with a third magnet. The commutator associated with the rising selector serves to make the transfer of the rack from the high to the low speed.

Line Finder Frame.—This frame is similar to the selector frame described, except that there are 10 banks instead of 5 and each bank has 40 sets of terminals instead of 100. On these terminals are connected the subscribers' lines, so that a total of 400 telephone lines can be accommodated by each frame.

This means that in a 10,000 line central office, there are required 25 line finder frames. The selectors, or *line finders*, on the line finder frame, are not under the control of any sender.

A line finder is sent upward by a so-called start circuit which functions when a subscriber lifts his telephone receiver off the hook.

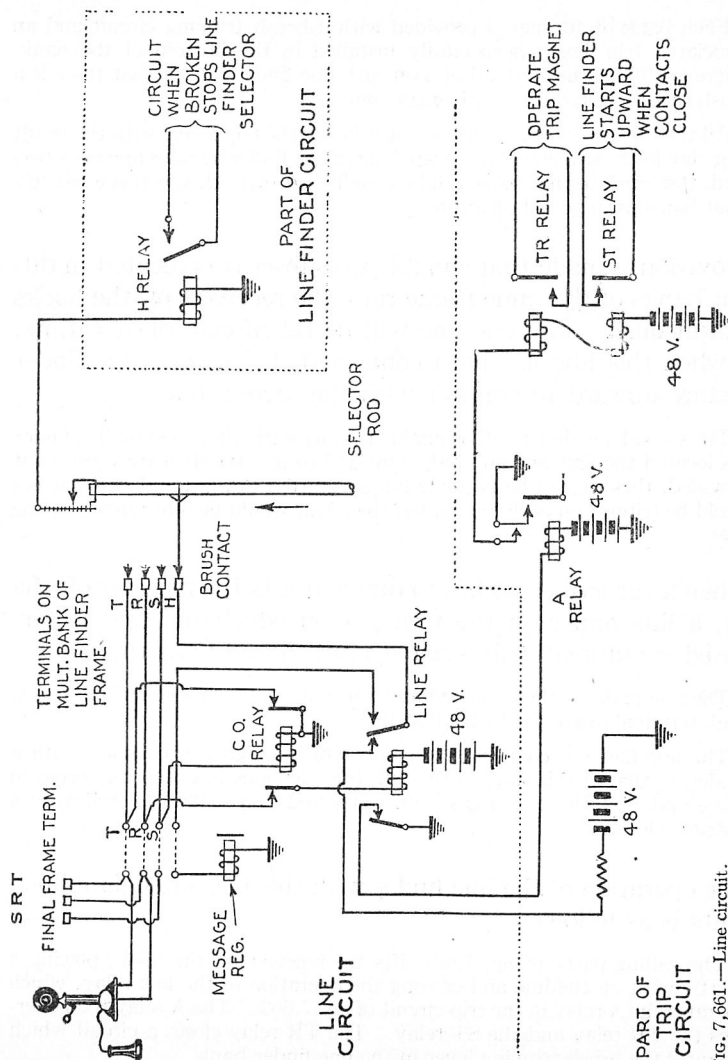


FIG. 7,661.—Line circuit.

FIG. 7,662.—Part of tripping circuit.

FIG. 7,663.—Part of line finder circuit.

Each bank of 40 lines is provided with a brush tripping circuit and an associated trip lever horizontally installed in the bottom of the bank. There are 10 brushes instead of 5 on each line finder rod, so that there is a brush capable of covering each entire bank.

All the brushes in each bank rest just below the trip lever, with the result that should the trip lever be operated and a line finder be subsequently operated, the brush in that bank will be caught and tripped, and this is exactly what happens in actual operation.

Provision is made that should two subscribers located in different banks of the same frame raise the receivers off the hooks simultaneously, only one line will be taken care of at a time, and when this line has been connected, the second line finder will start upward to connect with the second line.

The second line finder will be unable to start until after the first line finder has located the first line and has connected to it. If this feature were not provided, there would be two line finders started upward and two brushes would be tripped on each line finder; the result would be interference in the lines.

When a subscriber wishes to dial and lifts the receiver off the hook, a line finder on the frame upon which his line is terminated is automatically started upward and finds this line.

The line finder is then stopped and left with its brushes connected to the bank terminals associated with that line.

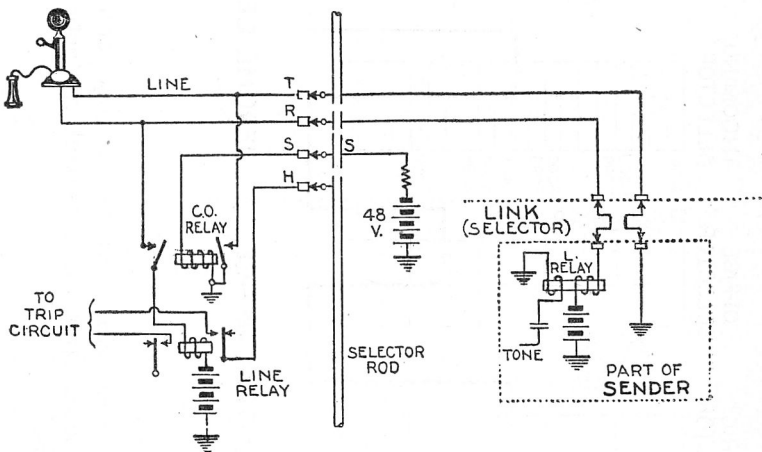
The line finder is connected to a *link* which assigns, or connects with a sender, so that at this stage of the call, the telephone has been connected to a line finder which in turn has been connected to a sender, as well as to a district selector.

The operation of the line finder with the associated simplified circuits is as follows:

The calling party of fig. 7,661 lifts the receiver off the hook, placing a short-circuit on the line and causing the operation of the line relay, which operates the A relay in the trip circuit of fig. 7,662. The A relay then operates the TR relay and the ST relay. The TR relay closes a circuit which operates the brush tripping lever in the line finder bank.

The ST relay closes a circuit which starts the associated line finder in its motion upward. After the line finder has advanced upward and its brush has been tripped, the tripping circuit is released through a segment on the commutator at the top of the line finder rod so that the tripping circuit may be used for tripping another line finder brush on another call.

The line finder now *hunts* for the line which has originated the call. The terminal H of that line is marked with *battery* from the contacts of the line relay so that when the line finder brush reaches this terminal and makes



FIGS. 7,664 and 7,665.—Line finder brushes stopped at calling line terminals and sender connected. The calling telephone receives the "dial" tone.

contact with it the H relay in the line finder circuit of fig. 7,663 operates, causing the line finder selector to stop. The CO relay is then operated and the line relay is released as shown in fig. 7,664.

The line finder is then connected by means of a link to an idle sender as shown in fig. 7,665, and the calling subscriber receives a *dial* tone which is a characteristic b-r-r-r sound to indicate that the sender is ready to receive the dialing.

District Selector Frame.—This frame has its selectors connected to the line finders, and the contacts on the multiple banks connected to the office selector frame.

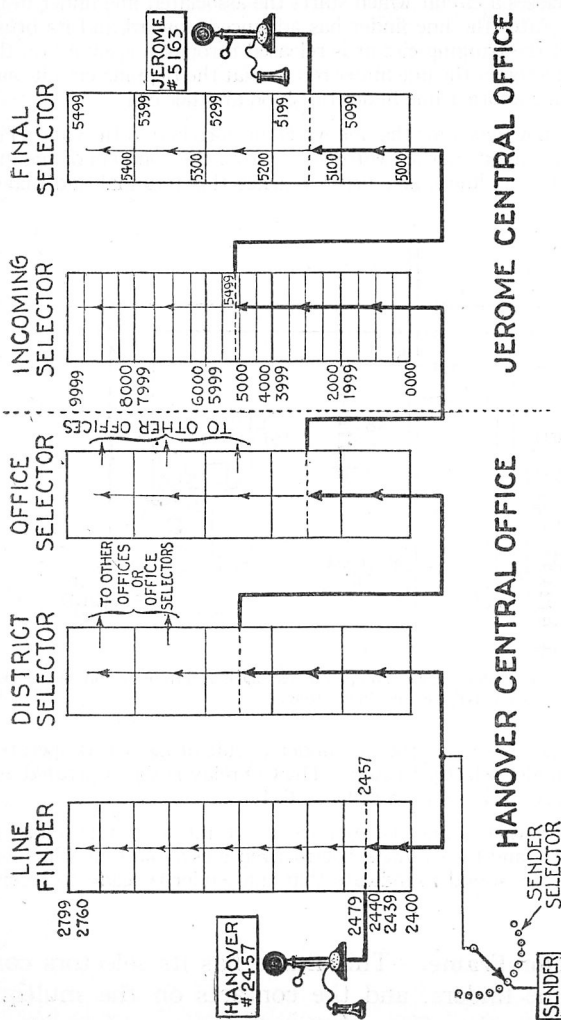


FIG. 7,666.—Panel dial system. Routing of a call.

Office Selector Frame.—The office selector frame has its selectors connected to the bank contacts on the district selector frame, and its bank contacts wired to incoming selector frames of distant offices.

Distant Central Office Incoming Selector Frame.—As previously mentioned, the trunks outgoing from the office selector frame multiple banks are cabled to the distant central office where they are terminated to selectors on the incoming selector frame, as shown in fig. 7,666.

Each incoming selector must have access to every line in the central office.

Since there are 10,000 lines in the central office, and only 500 terminal sets available on the entire five multiple banks of the incoming frame, it is necessary to introduce another selector frame before the actual subscriber line is reached. This is done by employing *final* frames, so that the incoming selector picks one of a group of trunks to certain final selectors, which in turn make the actual connection to the called line.

Final Selector Frame.—Each of the five multiple banks on the incoming frames are divided into four groups of 25 trunks each connected to final selectors on the final frame.

There are then 20 groups of trunks on each incoming frame and since there are available 500 line terminals on each final frame, the capacity of the central office will be 10,000 lines.

The terminals of the first group of trunks in the bottom bank, or *Bank O* of the incoming frame are connected to final selectors having access to the first 500 lines, or lines 0000 to 0499, the second group of terminals in the same bank of the incoming frame are connected to final selectors connecting with the next 500 lines, or lines 0500 to 0999, etc., as shown in fig. 7,666.

Ringling.—As previously mentioned, the generator current used to ring the called party is furnished through the incoming selector. An audible ringing tone is transmitted back to the calling party so that he may know that the bell at the distant end is being rung.

Message Registration.—Each subscriber's line has associated one message register, just as in the case of the manual central office system. This register is connected as shown in fig. 7,661,

and is operated automatically two seconds after the called party has removed the receiver off the hook. The registers in a dial office are treated very much like those in a manual office.

Disconnection.—When the conversation is finished and the called party hangs up, all the selectors involved in the call will not be released until the calling subscriber hangs up.

Busy Back.—The final selector makes a busy test on the desired line, and if it finds the line busy the final selector, instead of applying the ringing current, will cause an interrupted busy tone to be returned to the calling party.

The Special A Board.—In a dial central office there is also an operating room with a special A-board and a “cordless” B-board. These switchboards are manually operated and perform functions somewhat different from those in a manual central office.

For special reasons, some of which are commercial and some of which are limitations imposed by the mechanical system, it is not possible to allow a subscriber to automatically connect with certain distant central offices. The scheme then is to route his call to an operator at a special A position in the central office who will care for the connection desired. This is done by the calling party by dialing “O.”

The special A board framework is similar to that of the manual central office A board. Each operating position contains jacks and lamps to receive calls from the subscribers in the local area, and keys and dialing equipment to complete the calls. In addition there is in the jack panels a so-called *checking multiple* which is used by the special A operator when checking or verifying a particular telephone number from whence a long distance or toll call is being made.

This checking multiple consists of groups of brass pins, one for each subscriber number in the central office, arranged in the jack panels very much

like the multiple jacks on the manual B board. The pins are insulated from each other. The special A operator when verifying the telephone number of a calling subscriber, who has called the operator for a toll connection and has declared his number to her, touches the tip of a special cord at her position to the pin on the checking multiple corresponding with the number of the calling subscriber, and if this has been given correctly the operator will hear a distinctive tone.

The Cordless B Board.—The B-board of a dial central office is known as a cordless B-board, mainly because there are no

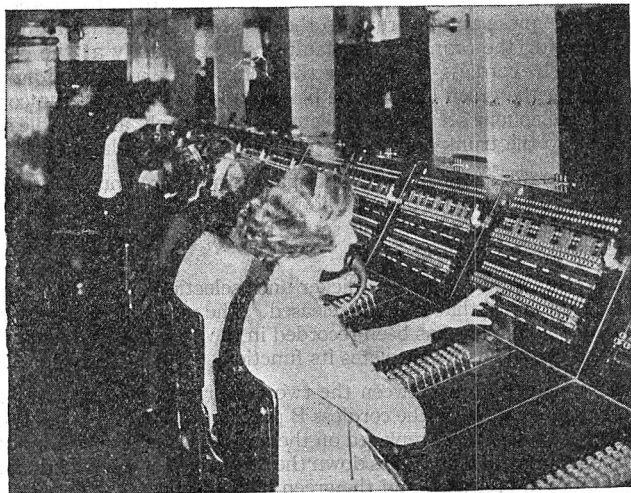


FIG. 7,667.—Cordless B board of a panel dial central office.

cords. This switchboard is used to complete connections for calls originating at manual central office areas.

The sections are constructed as shown in fig. 7,667 with a slanting top upon which are mounted keys and the lamps for approximately 60 trunks incoming from various manual central offices. These trunks are in most cases operated on *straight forward method*.

Each trunk has two lamps and two keys, as follows:

Guard lamp (Orange or White).

Busy lamp (Green).

Disconnect key (Red). Used only for call circuit trunks.

Assignment key (Green).

On each position is a set of numerical recording keys.

In operation, when a call for a subscriber in the dial central office area originates in a manual central office district, the A operator in the manual central office picks an idle trunk to the desired dial office (straight forward basis), causing the orange guard lamp to light steadily at the cordless B position. The cordless B operator then presses the associated assignment key, causing the green lamp to be lighted and to flash and the cordless B operator's telephone set to be connected to that trunk, also an idle sender is connected to the trunk and to the numerical recording keys.

The A operator at the manual office passes the desired number to the cordless B operator, over the trunk, who writes it on the numerical keys. The cordless B operator's telephone set is removed from the trunk and the orange lamp is extinguished.

The green lamp continues to flicker until selection is completed and then lights steadily until that trunk is released. The numerical keys are released as soon as the number has been recorded in the sender. The sender in turn is released as soon as it completes its function.

During conversation between the two subscribers the green lamp of the trunk remains lighted at the cordless B position. When the conversation is ended and the receiver is replaced on the hook and the A operator in the distant manual central office takes down the connection, the switches in the dial central office are released and the green light disappears. The same trunk is now ready for another call.

Step-by-Step Dial System.—The main difference between a step-by-step dial central office and a panel dial central office is in the design and operation of the automatic switching apparatus. In the *step-by-step system* the dial operates the selectors directly, each number dialed causing a different operation in the selectors and each operation occurring immediately as

the dial returns to its normal position, and when the last digit is dialed the connector actually makes connection with the telephone desired.

In the *panel dial system* the dial does not operate the selectors directly. The dial pulses at each dialing operation are discharged into the sender, causing certain circuit conditions

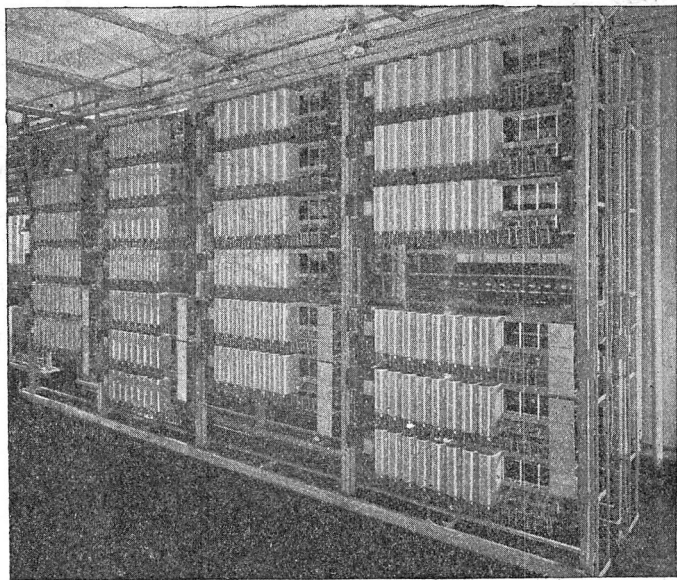


FIG. 7,668.—Step-by-step connectors mounted on switch frames.

to be set up in the sender circuit, which control the operation of all the selectors.

Theoretically, it is possible to have 10,000 lines in a step-by-step central office. However, on account of several practical limitations this system is not employed for such cases, the panel dial type being used instead.

In the most up-to-date step-by-step systems there are three distinct types of switches, namely:

1. Line finder;

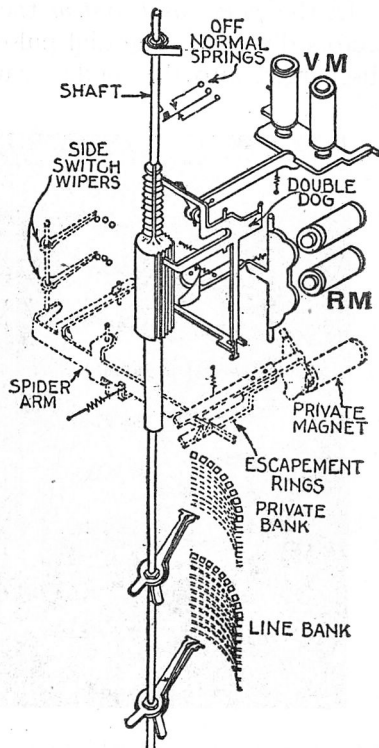
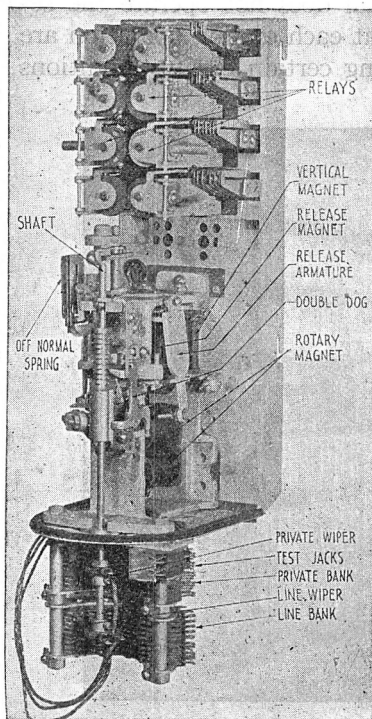


FIG. 7,669.—Step-by-step connector switch. It consists of a double bank and double wipers, or brushes, and a mechanism whereby the shaft can be lifted and rotated step-by-step. This is a two digit switch. The vertical motion is controlled by the first digit dialed and the rotary motion by the second digit.

FIG. 7,670.—Diagram of step-by-step connector switch simplified. At the lower end of the shaft are the double wipers. Further up on the shaft are vertical teeth by which the shaft is raised step-by-step by the magnet VM. Just below these teeth is a hub of rotary teeth by means of which the shaft is rotated step-by-step by the magnet RM. The coiled spring at the top of the shaft causes it to return to its initial rotary position when released, from whence it falls by gravity to its initial vertical position.

2. Selector;
3. Connector.

In the earlier systems instead of the line finder there is a line switch and master switch combination which will also be described in this chapter since many of these are still in operation.

In describing the apparatus it will be more convenient to start with the connector.

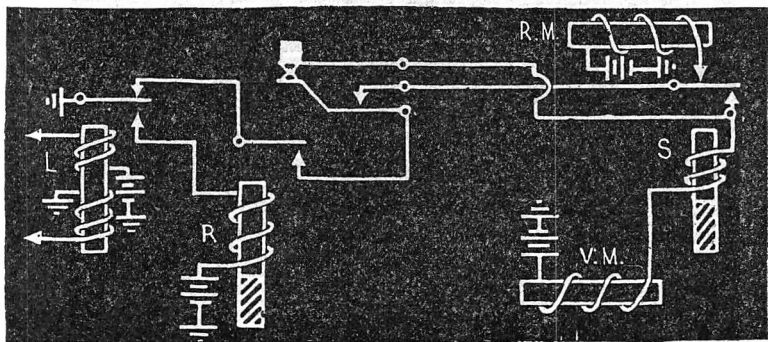


FIG. 7,671.—Step-by-step connector circuit. When this switch is first engaged the L relay and the R relay are operated. If the subscriber dials, say for example No. 46, the L relay is momentarily released and re-operated four times when the digit 4 is dialed, but the R relay remains in its initial operated position since it is a slow releasing relay. The interruptions at the L relay are transferred to the S relay which operates and remains operated since it also is a slow releasing relay, but the vertical magnet VM, operates four times, in unison with the breaks at the L relay. The vertical magnet VM causes the shaft wipers to be stepped upward to the fourth level on the multiple banks. When the wipers reach the first level, at the end of the first pulse, the off-normal springs are operated and transfer the pulsing path between the contact of the R relay and the contact at the S relay, but since relay S is slow to release, it remains up until the last pulse of the digit dialed, while the magnet VM, continues to operate and to release, thereby bringing the wipers to the fourth level. After the last pulse of the digit the S relay releases due to the long broken interval at the L relay contacts, and the pulsing circuit is then transferred from the vertical magnet VM, to the rotary magnet RM. When the subscriber dials the second digit which is "6", the L relay pulses six times and causes the rotary magnet to operate and to release six times, thereby stepping the wipers around to terminal No. 6 on the multiple bank. In dialing the digit 4 and 6 if the finger wheel of the dial be held off its normal position long enough for the L and R relays to release, the connector switch will be restored to normal by the release magnet (not shown) which operates when the R relay falls back and removes the double dog from the shaft, allowing the coiled spring at the top of the shaft to restore the shaft.

The Step-by-Step Connector.—In fig. 7,668 are shown several groups of connectors mounted on switch frames and in fig. 7,669 is shown one such connector with the cover removed. A simplified diagram of this switch is shown in fig. 7,670.

In order to make clear the operation of the connector a simplified diagram is shown in fig. 7,671 with the description of the pulsing circuit and the movement of the shaft carrying the wipers or brushes.

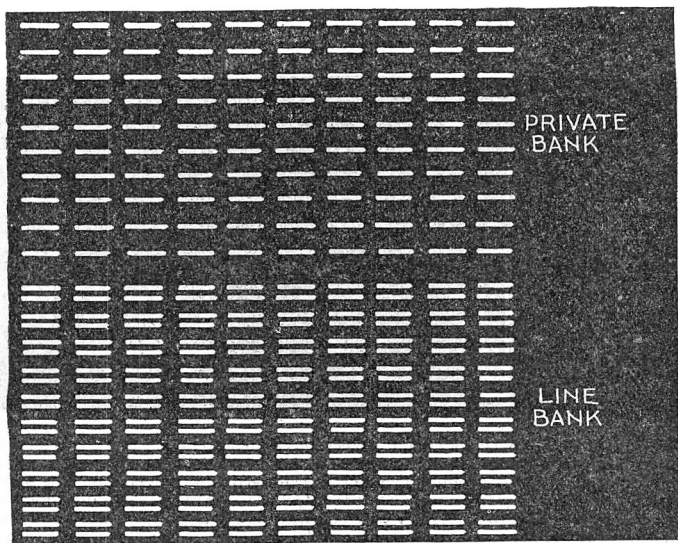


FIG. 7,672.—Diagram showing contacts of line and private banks of a 100 line system. These banks form a part of the connector switch.

The connector makes a busy test in accordance with fig. 7,673. If the line called be idle, a switching relay in the connector circuit (not shown) will operate when relay A falls back and connects ringing current to the line. When the called subscriber answers, another relay in the connector circuit (not shown) operates, causing the ringing current to be removed and the line to be connected through for talking.

While the called party is being rung, the calling subscriber hears an audible ringing tone as an indication.

The Connector Bank.—As shown in fig. 7,669 the multiple banks are bolted to the connector by bank rods which pass through bank rod holes in the banks. The bank and bank rods can be removed as a unit by removing the nuts at the top of the bank rods.

The upper or *private* bank is made up of 100 brass terminals arranged in an arc in ten levels of ten terminals each.

The terminals are insulated from each other and the adjacent levels are separated by thick insulators.

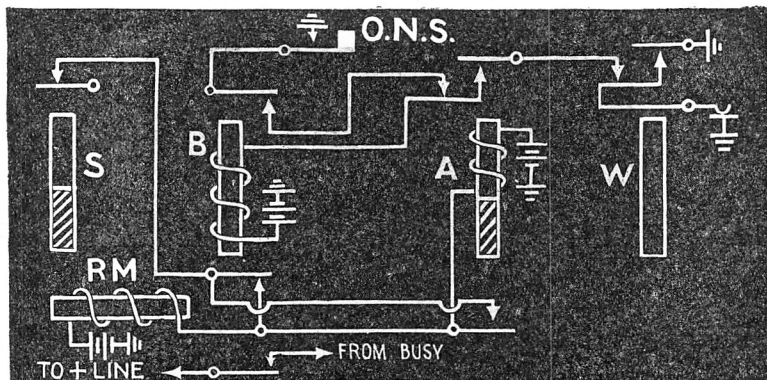


FIG. 7,673.—Busy test circuit of connector. Relay A is a slow releasing relay and has operated in parallel with the rotary magnet RM. Relay A will remain up for a moment after the last rotary impulse has been received. If the called line be busy its sleeve (private) terminal has ground connected to it and causes relay B to operate through the private wiper and front contact of relay A. After relay A has released, the B relay remains locked up through its own contact and O.N.S. springs. Relay B also opens the circuit of the rotary magnet RM, so that further dialing by the subscriber will have no effect, and connects busy tone to the tip side of the line to advise the calling subscriber that the line desired is busy.

The lower or *line* bank has 200 brass terminals arranged in vertical pairs and also mounted in an arc in ten horizontal rows or levels of ten pairs of terminals each.

The upper and lower terminal of each pair are separated by an insulator and the adjacent levels are separated by two thicker sheets of insulating material.

The terminals of each bank and the insulating material are assembled one above the other and clamped into a frame by five bolts. The terminals are double ended, the outer end forming a soldering lug for the multiple bank wiring and the inner end forming a contact over which the brushes wipe. Fig. 7,672 is a diagram of the multiple bank contacts.

The Step-by-Step Selector.—In fig. 7,674 are shown several groups of selectors and in fig. 7,675, one such switch. It will be seen that there is very little difference in the mechanical construction between this switch and the connector in fig. 7,669.

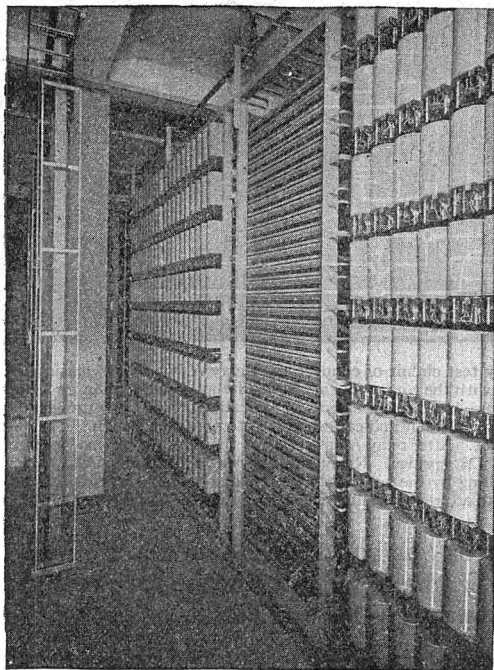


FIG. 7,674.—Groups of selectors mounted on switch frames.

The selector operates also in a similar manner to the connector except that it requires the dialing of only one digit, which raises the wipers to the

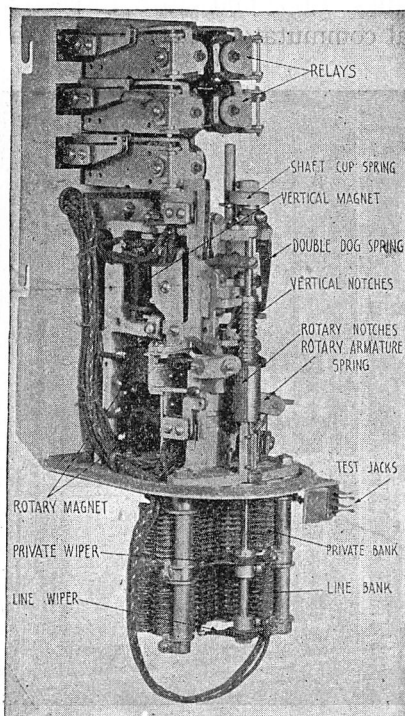


FIG. 7,675.—Step-by-step selector. It consists of a multiple bank and wipers and a mechanism similar to the connector in fig. 7,669. This is a one digit switch. The vertical motion is controlled by the dial, and the rotary motion automatically.

level dialed. Then, without further dialing, the selector mechanism immediately starts the rotation and sweeps the wipers step-by-step over the row of bank contacts in the process of finding an idle trunk to another group of selectors or to a particular group of connectors.

The Step-by-Step Line Finder.—In fig. 7,676 are shown several groups of line finders mounted on switch frames. In construction and operation this switch is similar to the connector and selector of figs. 7,669 and 7,675, respectively, except that it has a vertical commutator at the side of the banks and an

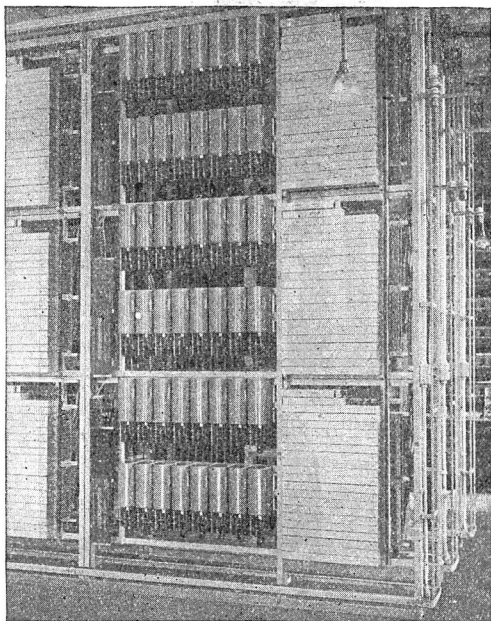


FIG. 7,676.—Groups of line finders on switch frames.

additional brush on the shaft to sweep over the contacts on the commutator so as to control the vertical movement of the wiper shaft. The line finder does not require any dialing. It is self-pulsing and is started by the lifting-off of the receiver from the switch hook.

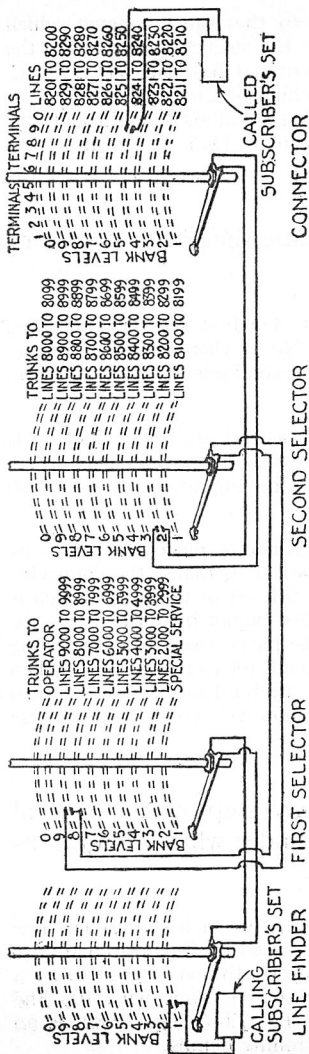


FIG. 7,677.—Progress of a step-by-step call in a four digit central office, using line finders.

The instant the receiver is removed from the hook of a subscriber line connected to the multiple banks the line relay of the subscriber line operates and closes a circuit which starts the line finder and causes it to step its wipers up to a level on the banks where the line is located and then immediately the wipers are rotated and stopped at the contacts associated with the subscriber line originating the call. All this stepping of the line finder wipers is accomplished without any dialing on the part of the calling subscriber.

Progress of a Call.—Fig. 7,677 represents in a general way all the equipment involved in a call through a step-by-step central office with four digit numbers. It will be noted that two selectors are required. If this were a three digit system only one selector would be necessary. The line dialed is No. 8,429.

When the receiver of the calling subscriber is removed from the hook, the *start circuit* functions to choose the next idle line finder. The circuit is then arranged so that the shaft of the line finder is stepped up until the commutator brush reaches the first segment which (in this case) is grounded by the operation of the group start relay. No further stepping takes place.

The stepping circuit is now transferred to the rotary magnet which operates and steps the brushes around until the sleeve brushes reach the terminal associated with the line. This terminal has had battery connected to it and causes the horizontal switching of the brushes to be arrested and the connection to be made with the calling line through the line finder brushes and to an idle first selector. Dial tone is now sent back to the calling subscriber by the selector.

It must be remembered that no dialing has been necessary so far.

Next, the calling subscriber dials the No. 8. The first selector is actuated by eight pulses and steps the wipers to level No. 8 where it makes connection with the first idle trunk to a group of ten second selectors having access to lines 8000 to 8999.

When the next digit (No. 2) is dialed the second selector picked up is actuated by the two pulses and steps its wipers to the second level where there are trunks to a group of ten connectors having access to lines 8200 to 8299.

The subscriber now dials No. 4 and the connector picked up, steps its wipers to level 4 and when the next digit (No. 9) is dialed the connector mechanism rotates the wipers around to the 9th set of terminals which is connected to the line desired. If the line called be not busy the connector places ringing current on the line. When the party answers, this ringing current is tripped off and the line is cut through for conversation. When the parties hang up at the end of the conversation all the switches return to normal, the calling subscriber's telephone, however, controls the release of all the switches.

Line and Master Switches.—In many step-by-step central offices there is used instead of the line finder what is known as a line and master switch combination.

There is a *line switch* connected permanently to each subscribers' line in the central office. The line switches are placed on line switch frames in groups of 25, 50, 75 or 100 and each group controlled or guided, by a *master switch*. Fig. 7,678 represents a line switch frame with 100 line switches which are constructed as shown in fig. 7,680; fig. 7,682, is an enlarged view of the master switch and controlling details.

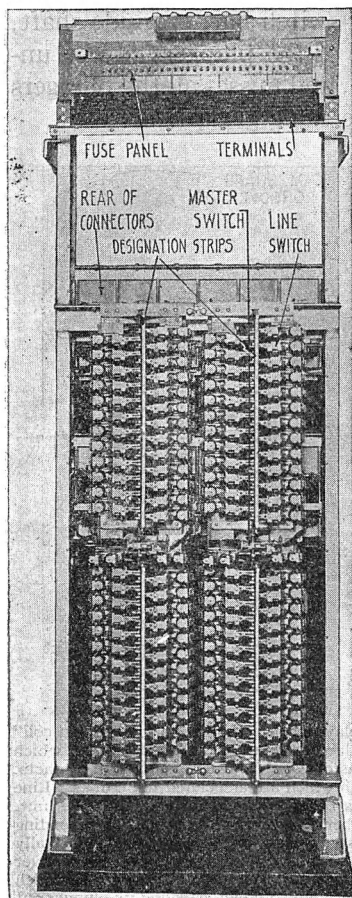


FIG. 7,678.—100 line switch board *front view*. Here are shown 100 subscribers' line switches mounted on a steel frame in four sections of 25. Two sections of 25 are mounted on each swinging shelf and each shelf of 50 is controlled by a master switch. Above the switches may be seen the power panel and terminal assembly.

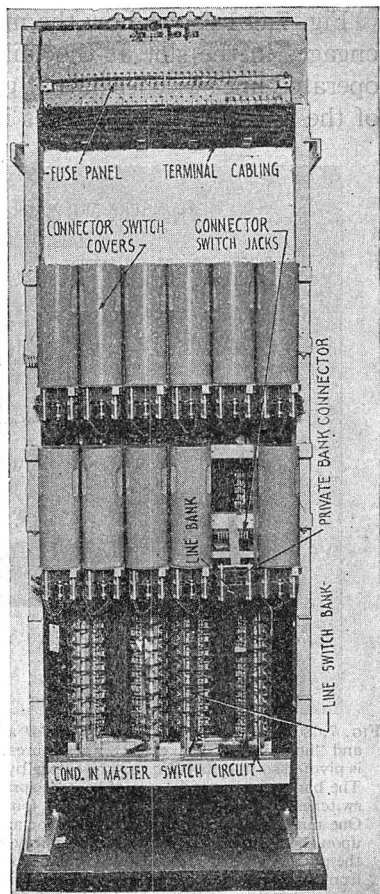


FIG. 7,679.—100 line switch board *rear view*. On the rear of a line switch unit are mounted the connectors which serve that 100 lines. The incoming subscriber's lines, besides being connected to the line switches are also connected to the connector bank contacts.

Fig. 7,681 shows how the master switch bar, or guide shaft, engages in the slot at the tail end of the plungers of the unoperated line switches in that group, and misses all the plungers of the operated line switches in the same group.

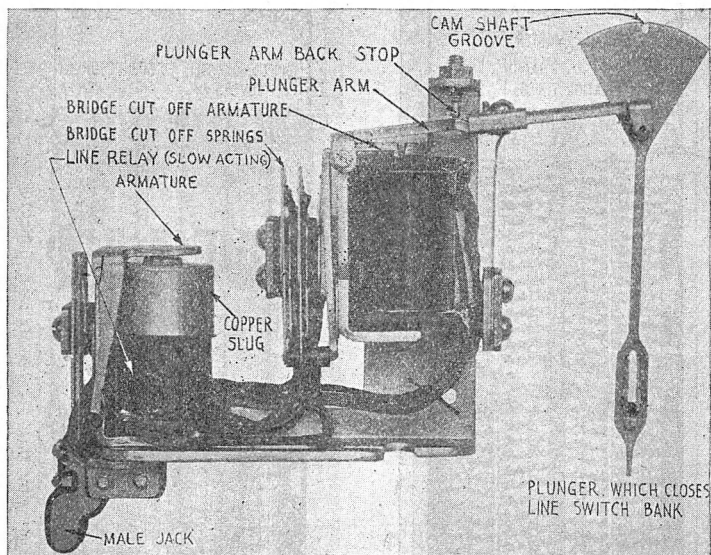


FIG. 7,680.—Line switch. *It consists of a line relay and a combination "pull down coil" and "holding coil" carrying two armatures. The larger armature carries a plunger, which is pivoted so that its point may be swung by the master switch in front of a bank of contacts. The bank consists of 10 sets of contact springs with which are associated ten trunks. Line switches are mounted in groups of 25, four groups being provided for each 100 line unit. One master switch may be provided for any number of groups of line switches depending upon the trunking capacity desired, since each master switch controls ten trunks. Normally the plungers are at rest poised over bank contacts. When a subscriber removes his receiver from his telephone switch hook preparatory to making a call, a circuit is thereby closed which causes the plunger arm of his line switch to be at once pulled down, carrying its plunger out of engagement with the master shaft and thrusting it into the bank. The effect of this is to connect the subscriber's line to a trunk leading to an idle first selector switch, as shown diagrammatically in the right hand portion of fig. 7 685. The instant that one line switch thrusts its plunger into the bank, thus occupying the trunk over whose multiple all idle plungers have been poised, the master switch operates and swings the remaining idle plungers forward over the next multiple of bank contacts. If this trunk should be busy, the movement proceeds until an idle trunk is found. It is to be noted that a line switch always uses a pre-selected idle trunk instead of making a selection after a subscriber starts to call.*

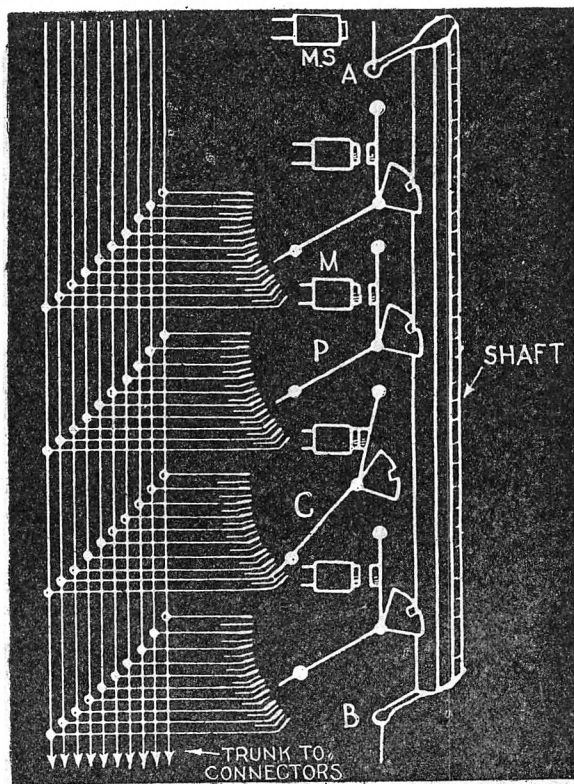


FIG. 7,681.—Diagram of line switch and connections. The switch *consists of* a magnet **M**, and plunger **P**, whose head or wing is slotted so that it may engage a projecting edge of the shaft. The shaft is pivoted at **A** and **B**, and is capable of a rotary motion of about 40 degrees under control of a master switch **MS**. The rotary motion causes the plungers of the various line switches to oscillate in front of the terminal of the trunks to the selector switches. Under control of the master switch the shaft comes to rest *only* opposite an idle trunk. If the shaft be holding all the plungers opposite, say the second trunk, and a subscriber remove his receiver, the corresponding plunger will *plunge in* and extend the connection to the selector associated with trunk number two. The plunger when *plunged in* is now free of the shaft as shown at **C**. The master switch, by means of the shaft moves the remaining plungers opposite an idle trunk, giving what is called *pre-selection of trunks*. When the subscriber who plunged in on trunk No. 2, hangs up his receiver, his plunger will come out of the bank but the slot in the wing of the plunger will not engage the shaft at this time. Hence this plunger will remain opposite trunk No. 2, until the shaft again swings in front of this

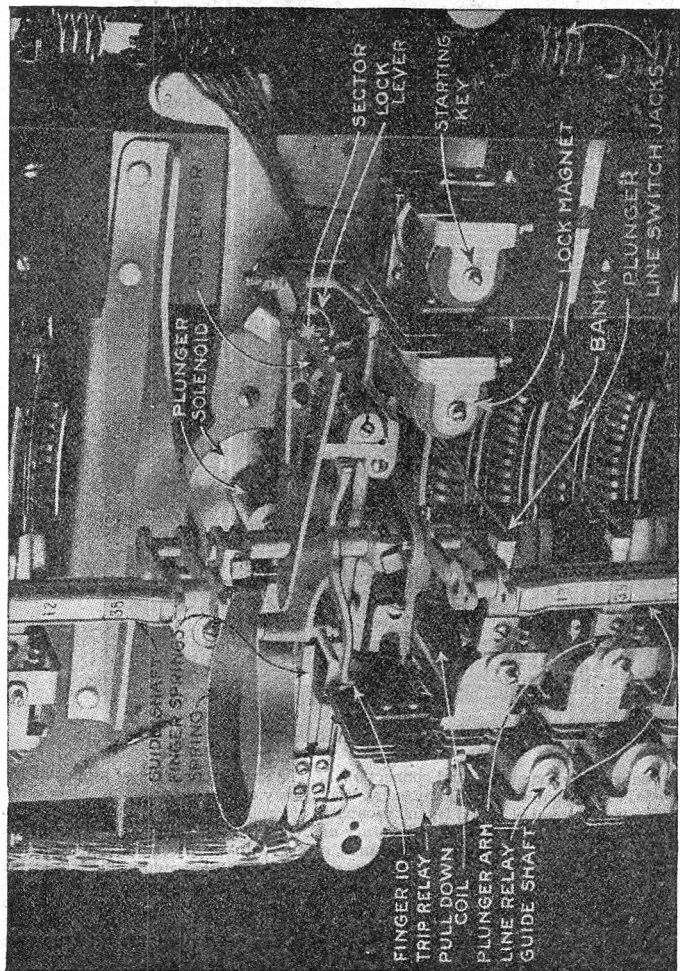


FIG. 7,682.—Master switch mechanism on line switch frame.

FIG. 7,681.—Text continued.

trunk and picks it up. To prevent a caller connecting on a busy trunk, a plunger must not plunge in while the master switch is seeking an idle trunk. This requirement is met by what is called the *open main battery feed*.

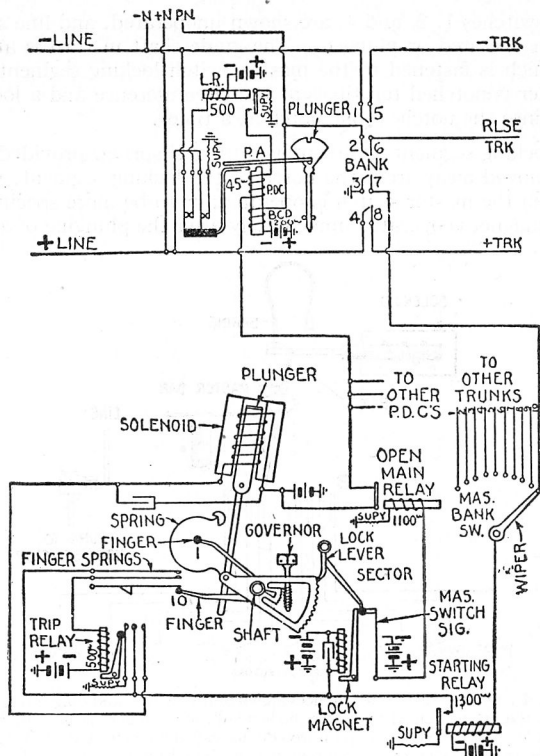
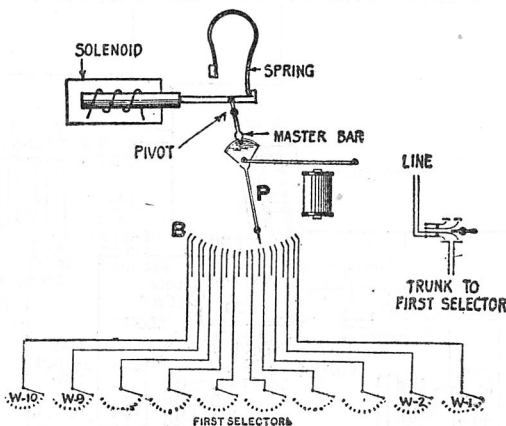


FIG. 7,683.—Line and master switch circuit. When the receiver (not shown) is taken off the hook the LR relay operates which in turn energizes the 45 ohm winding (P.D.C.) of the plunger relay and causes the plunger to be squeezed into the contacts of the line switch bank, thereby connecting the telephone with an idle trunk, or idle selector, as shown in fig. 7,685. The selector circuit then furnishes ground over the RLSE TRK lead which energizes the 1,200 ohm winding (BCD) of the plunger relay to lock the plunger in the operated position since the original operating path through the relay LR was broken upon the operation of the plunger. Ground is also sent to the master switch wiper, through line switch bank contacts 3 and 7, which causes the operation of the starting relay. The starting relay in turn operates the lock magnet relay which disengages the lock lever from the locking segment associated with the master switch and allows the guide shaft which is controlled by the U spring under tension, to rotate one notch so as to move the line switch plungers from right to left. The master switch wiper remains grounded while the associated trunk is busy, therefore, the starting relay does not release until the wiper by rotating has found a contact associated with an idle trunk. When an idle trunk is found the starting relay and the lock magnet relay release. This allows an idle line switch in the same group to operate. Each time that the lock

Line switches 1, 2, and 4, are shown unoperated, and line switch No. 3 is shown operated or plunged. The guide shaft in turn is attached to a lever which is fastened to the master switch locking segment A or at B. The latter is notched ten times at the circumference and a locking arm is pressed into the notches (one notch at a time).

The locking segment can be moved by a U. spring, provided the locking arm is moved away from the notch of the locking segment, which is the case when the master switch is operated; or to be more specific, when the locking magnet is operated immediately after the plunging of a line switch.



FIGS. 7,684 and 7,685.—Master switch mechanism of line switch and diagram of trunks to first selectors. In the line switch, the notch in the head of each plunger meshes with a rocking bar or "guide shaft" as it is called. A step by step device called a master switch (seen in the upper part of the figure) is connected to each pair or to each four guide shafts and by means of them can swing the plungers back and forth, step by step over the banks of contact springs. The plungers are normally held in position by the master bar, which carries a feather fitted into the slots at the rear of the plunger. When the line switch operates, the plunger point is thrust into the bank, connecting the line to the selector trunk, and at the same time disengaging itself from the master bar. The master switch is now automatically unlocked and begins to move under the action of the curved spring until an idle trunk is reached. When the master switch reaches the end of its stroke, the solenoid is energized and this pulls the shaft back in the opposite direction against the action of the spring.

FIG. 7,683.—Text continued.

magnet relay operates, the master switch shaft is rotated by the U spring so as to move the line switch plungers from right to left until trunk No. 10 is reached when a circuit is closed through the finger springs (by means of the finger on the segment) which energizes the solenoid and allows the solenoid plunger to move the master switch shaft in a direction against the spring tension to give this spring energy for another cycle. This operation is repeated.

Because of the mechanical arrangement in the master switch, the locking segment moves only one tenth of its full travel or one notch at a time, which corresponds to one trunk when the position of the line plungers in the line switch bank is considered. When the locking segment has moved from position 1 to 10, in steps as outlined above, a circuit is closed which sends electric current into the solenoid, which pulls its plunger. The latter, in moving, puts more tension on the U spring by bringing its two ends closer together.

This tension is utilized in moving the locking segment from position No. 10 to the starting position No. 1 and then in succession to position No. 10 again, as outlined above. The speed of the locking segment is controlled by a small governor and a system of gears.

Operation of Line and Master Switch.—Fig. 7,683 outlines in detail the circuit operation of the line and master switch combination. The line switch bank has connected to it trunks leading to first selectors, as shown in fig. 7,684.

When the line switch plunger has operated, the calling subscriber is connected to an idle first selector which sends back *dial tone* to indicate that the switches are ready for the dialing operation. From this point on the circuits and the equipment function as outlined in fig. 7,677.

Dial Private Branch Exchanges.—The dial private branch exchanges employ step-by-step type switching apparatus, and are designed to meet the same service requirements as manual private branch exchanges.

A great many of these P. B. X.'s have a manually operated switchboard used for central office connections and certain classes of tie lines to other P. B. X.'s.

When a manually operated switchboard is used with the step-by-step switching apparatus the system is known as a *semi-mechanical P. B. X.*

The P. B. X. systems are further classified according to the line capacity and the arrangement of selectors and connectors as follows:

1. Two digit system.—100 line capacity;
2. Combined two and three digit system.—200 line capacity;
3. Three digit system.—1000 line capacity;
4. Combined three and four digit system.—over 1000 lines.

Each semi-mechanical P. B. X. consists of:

1. A manual switchboard similar to the one in fig. 7,570;
2. Line switch frames with line and master switches, similar to the one shown in fig. 7,678 with connectors as in fig. 7,679 on the rear side;
3. A selector frame with selectors of the same construction as the one shown in fig. 7,675 (when required);
4. Relay racks with relays for central office trunks, tie lines, attendant trunks, etc.;
5. Main distributing frame for terminating the central office feeder cables, house cables, extension lines and trunks;

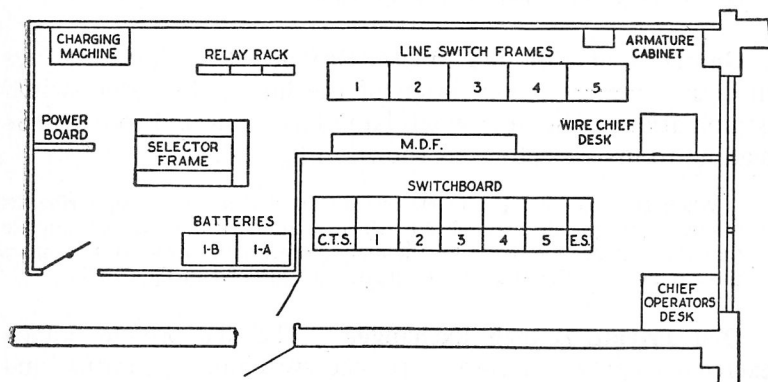


FIG. 7,686.—Typical floor plan of three digit step-by-step Private Branch Exchange.

6. A power plant consisting of a storage battery, a power board with controlling equipment and meters, a ringing machine and a charging machine;

7. Station equipment comprising the telephone instruments with dials and bells.

The apparatus is installed in the subscriber's premises in regular order, similar to fig. 7,686.

In the latest development of step-by-step P. B. X.'s the line finder has replaced the line and master switch combination as in the case of the step-by-step central office.

In operation:—Calls from extension to extension are handled with the step-by-step switching apparatus by dialing the proper number.

Calls from the central office into the P. B. X. are routed to the manual switchboard and are completed to the extensions by the operators. Calls from the extensions out to the central office may be dialed direct or they

may be routed to the local P. B. K. operator who then completes the connections.

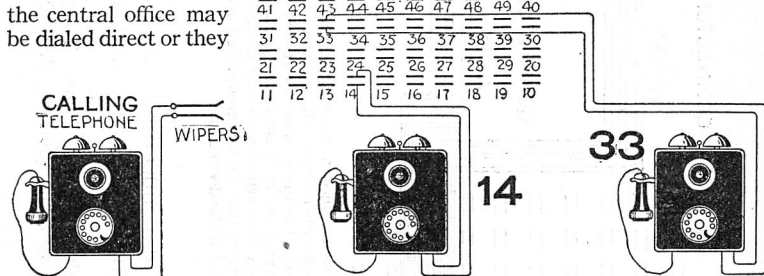


FIG. 7,687.—Diagram of line bank contacts, associated with each connector and numbering system of the telephone lines of which they are the terminals. The number of any set of terminals can be determined by noting the number of vertical and sidewise steps the wipers must be given to reach that set, remembering that ten steps are always represented by zero. Thus six vertical steps and ten rotary steps would cause the wipers to reach contact No. 60.

In the case of a small two digit system there are no selectors, the dialed connections being cared for by a so-called selector-connector, which is similar in construction to the connector and does the work of both the selector and the connector.

The selector-connectors are wired either to line finder or line and master switches.

The banks of the selector-connectors are wired to the extension telephones as shown in fig. 7,687, except that the top level or terminals 00 to 09 inclusive are wired to attendant trunks to the local P. B. X. switchboard. To dial the switchboard it is only necessary to dial "O," and to connect with an extension, two digits must be dialed.

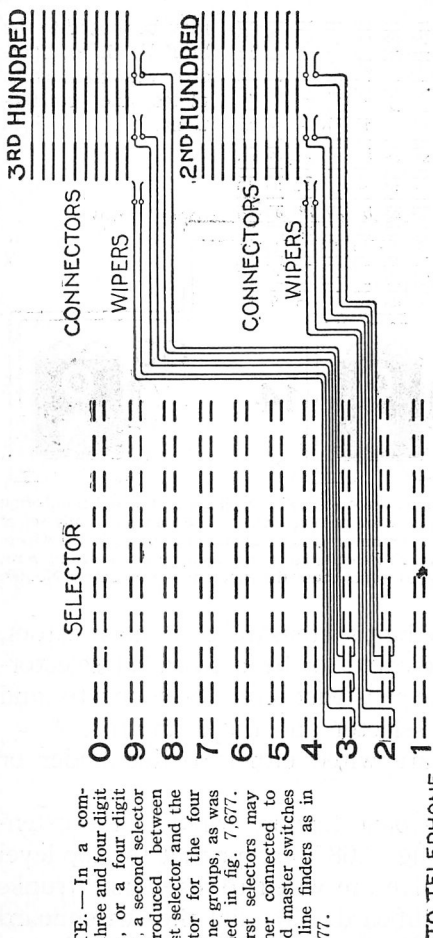


Fig. 7,688.—Diagram of a 200 line office in its simplest form. Lifting the receiver of the telephone connects the calling subscriber with an idle selector. The numbering of the telephones in this office is from 200 to 300 inclusive since the second and third levels of the selectors are used. Dialing the first figure (a 2 or 3) steps the selector up to the second or third level and wipers automatically rotate to select an idle connector serving that 100 line group. This action is independent of the calling device. The last two figures dialed cause the connector to pick out the desired line.

In a three digit system a selector and a connector is used for each connection. The selectors may be wired either to line finders or to line and master switches.

The selectors and the connectors are wired as shown in fig. 7,688. To make connection with any extension it is necessary to dial three digits, and to reach the local P. B. X. operator it is necessary to dial "O,"

TEST QUESTIONS

Panel System

1. *From what does the panel dial system derive its name?*
2. *What is the difference between the panel dial system and the step-by-step dial system?*
3. *How is the selection of a particular brush made?*
4. *What is the function of the commutator on a selector rod?*
5. *What is the duty of the "sender"?*
6. *Name the selectors controlled by dialing the central office code.*
7. *What is a "call indicator position"?*
8. *Describe the cordless B-board and explain its function.*
9. *In the automatic setting up of a complete connection, what selectors are involved?*
10. *When is the sender released from the call?*
11. *Explain the operation of a line finder?*
12. *What would happen if two line finders were started simultaneously?*
13. *What circuit receives and stores the dial impulses?*
14. *How many final selector frames are required in a central office of 6,000 lines?*
15. *How many line finder frames are required?*

TEST QUESTIONS***Step-by-step System***

1. *Describe the step-by-step action of a selector.*
2. *What is the main difference between the connector and the selector?*
3. *What is the function of a line switch?*
4. *What is the function of a line finder?*
5. *What is the duty of the master switch?*
6. *Compare a line finder and a selector.*
7. *Where is terminal 35 located on the connector bank?*
8. *What causes a line switch to plunge?*
9. *When a subscriber lifts the receiver off the hook and operates the line switch, and is connected to a selector, what may cause the line switch to release and to plunge again in rapid succession?*
10. *Explain what apparatus operates and is tied up as a result of the receiver being accidentally knocked off the hook.*
11. *What switch furnishes the talking battery?*
12. *What switch furnishes the dial tone?*
13. *What switch applies the ringing current to the line?*
14. *Name the apparatus involved and describe the operation when a complete connection is set up:*
 - a. *In a 2 digit system.*
 - b. *In a 3 digit system.*
 - c. *In a 4 digit system.*

CHAPTER 189

The Telegraph

The telegraph is *an electrical apparatus for transmitting messages between distant points.*

The simplest form of telegraph consists of

1. Key or transmitting instrument.
2. Line wire.
3. Sounder or receiver.
4. Battery or other source of electricity.

Classification.—The telegraph, like other inventions, has been considerably developed, resulting in numerous systems. A classification of these various systems, to be comprehensive, must be made from several points of view, as with respect to:

1. The kind of circuit, as
 - a. Ground return;
 - b. Metallic.
2. The method of operating the circuit, as
 - a. Closed;
 - b. Open.

3. The transmitting capacity.

a. Single Morse line;

b. Duplex.

c. Duplex { single current or differential;
double current;
polar;
bridge;
high pressure "leak";
high efficiency;
city line;
short line.

d. Quadruplex. { gravity battery;
Jones;
Field;
Davis-Eaves or Postal squad;
single dynamo;
metallic circuit;
Gerritt Smith;
Western Union;
British post office.

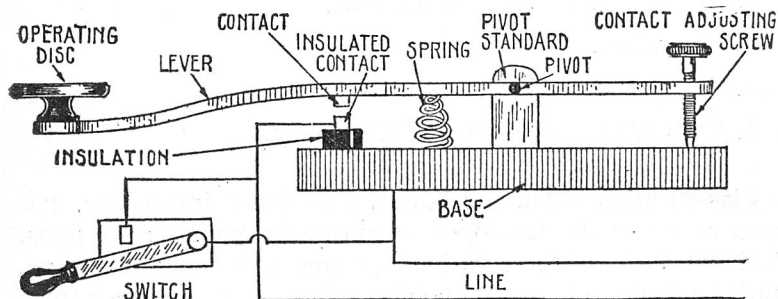


FIG. 7,689.—Elementary key. In actual construction the switch is attached to the base, but is here shown separately, in order that the connections may be more plainly seen.

e. Multiplex { synchronous.

f. Phantoplex.

4. The method of receiving, as

a. Non-recording

b. Recording { by perforations;
by printing.

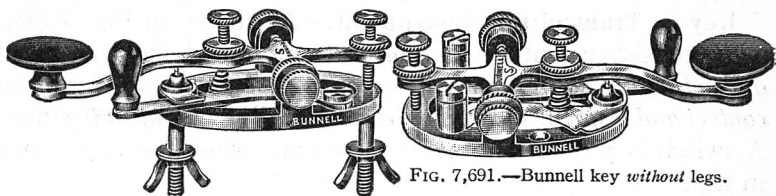


FIG. 7,691.—Bunnell key *without* legs.

FIG. 7,690.—Bunnell key *with* legs.

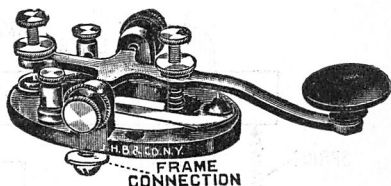
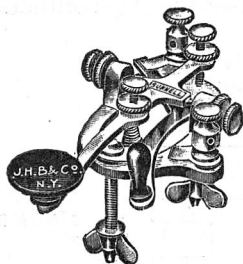


FIG. 7,692.—Fry open circuit key. *It has a circuit closer which must be worked like an ordinary key. With circuit closer in closed position, the battery cannot be put to line or short circuited by pressing down on key lever, hence leaving a book or other heavy object on key does not waste the battery, but the relay is always in circuit ready to receive signals.*

FIG. 7,693.—Bunnell open circuit key. *When it is preferable to use dry cells instead of closed circuit cells this type of key is recommended. Even though a closed circuit be maintained for communication in either direction no current is being used except when key is depressed. Each individual station supplies its own current.*

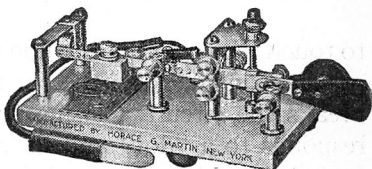
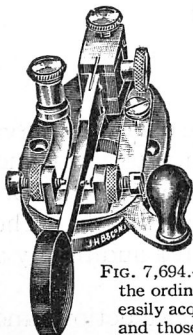


FIG. 7,694.—Bunnell double speed key. *It requires only one-half the motions of the ordinary key, and these are made by a sidewise rocking motion of the hand, easily acquired, which guarantees that operators will not be affected with cramp, and those who are so affected will soon recover their speed.*

FIG. 7,695.—Bunnell vibroplex key.

Key or Transmitting Instrument.—As shown in Fig. 7,689, a key consists essentially of a *pivoted lever provided with a contact and adjusting screw, and carried on a base having an insulated contact and a spring to keep the lever normally in the open position.* A switch is provided to close the circuit when the key is not in use.

In operating the key, its operating disc is grasped by the 1st, 2nd, and 3rd fingers; depressing the disc causes the two contacts

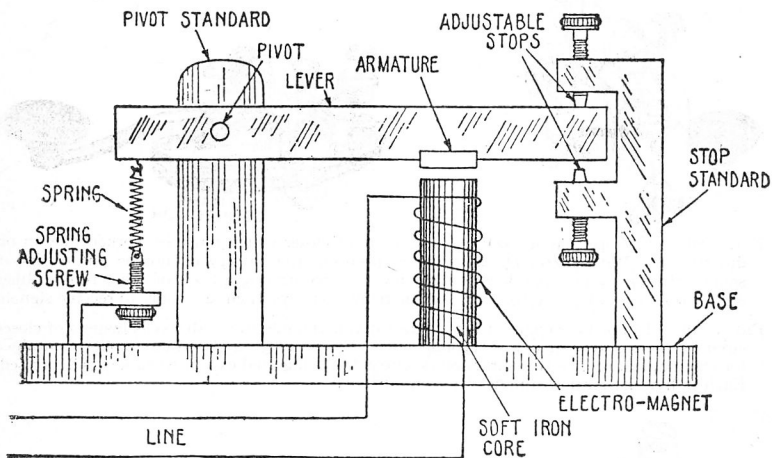


FIG. 7,696.—Elementary sounder showing essential parts.

to touch, thus closing the line circuit. When the operator ceases pressing on the disc, the spring forces the contacts apart and breaks the circuit. Closing the circuit for a short period corresponds to a “dot” and for a longer period, to a dash. The periods in which the circuit is closed are indicated audibly by a “sounder.”

Figs. 7,690 to 7,695 show the actual construction and appearance of modern keys now in use.

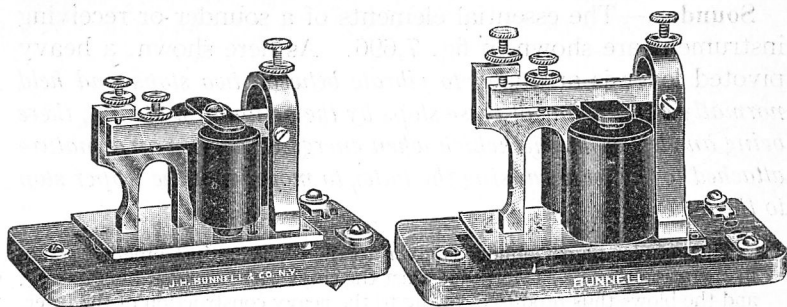


FIG. 7,697.—Bunnell aluminum lever giant sounder. Sounders wound to 4 ohms can be used on lines up to $\frac{1}{4}$ mile in length; while 20 ohm sounders will operate on main lines up to 15 miles in length, without using a relay.

FIG. 7,698.—Bunnell 1892 giant sounder with aluminum or brass lever.

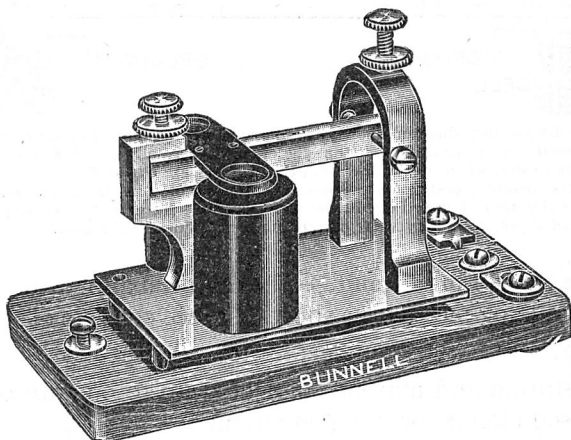


FIG. 7,699.—Ghegan alternating current sounder. *It can be used on any 110 volt, 60 cycle a.c. circuit, the method of connecting depending on the resistance of the winding used. Wound with high resistance for 110 volt, 60 cycle circuit through a condenser of one-half m.f. capacity, which is connected in series with the sounder. By giving the lever plenty of play between stops the sounder may be connected direct to the 110 volt, 60 cycle circuit. However, the series condenser is recommended as the lever play may be adjusted to suit and the current consumption is reduced to about ten milli-amperes on closed circuit. The low resistance type is to be used in the secondary of a small socket transformer, as shown in its blue print.*

Sounder.—The essential elements of a sounder or receiving instrument are shown in fig. 7,696. As here shown, a heavy pivoted lever is arranged *to vibrate between two stops and held normally against one of these stops by the action of a spring, there being an electro-magnet which when energized acts on an armature attached to the lever causing the latter to move from the upper stop to the lower stop.*

The popular name sounder is given to the receiving instrument because in operation the lever is forced against the stops with considerable rapidity, and the blows thus produced, owing to the heavy construction of the lever, are distinctly audible.

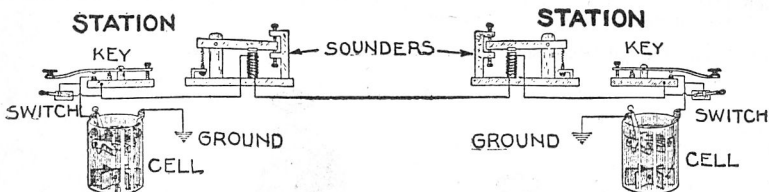


FIG. 7,700.—Elementary diagram showing a simple short line **closed circuit** system. It is called a closed system from the fact that the circuit is normally closed with current on the line, that is to say, when not in operation the switches are closed and current flows which energizes the magnets and holds the instrument armatures in the down position. This necessitates the use of a closed circuit cell as for example the crow foot gravity type which is capable of supplying a very weak current for a long duration of time.

Simple Short Line Circuit.—The essential apparatus required for transmitting messages a short distance consists of

1. Key.
2. Sounder.
3. Battery

at each station and may be connected up to operate on either

1. Closed circuit, or
2. Open circuit.

The closed circuit arrangement is shown in fig. 7,700.

NOTE.—An advantage of the open circuit system is that when not in use, the battery is not required to supply current to the line; another advantage is that the resistance of the sounder (or relay) is not always in the circuit, since the closing of a key cuts out the relay. On relay lines local sounders or registers are provided. In some cases a "telltale" galvanometer is placed in the main line at each station to indicate to the operator the condition of his transmitted signals, etc.

It is so called because both switches are kept closed except during operation, when the sender's switch remains closed. It would naturally be supposed that keeping the circuit closed for long intervals would exhaust the battery, but it does not because owing to the high resistance of the magnet on the sounder, very little current flows; moreover a battery designed for closed circuit is used.

The open circuit system is shown in fig. 7,701.

In this arrangement the only instruments necessary are a key with insulated contacts, a sounder, and cell at each station. One insulated contact of each key is connected to the cell, and the other insulated contact is connected in series with the sounder and the latter grounded as shown. The base of each key is connected to the line.

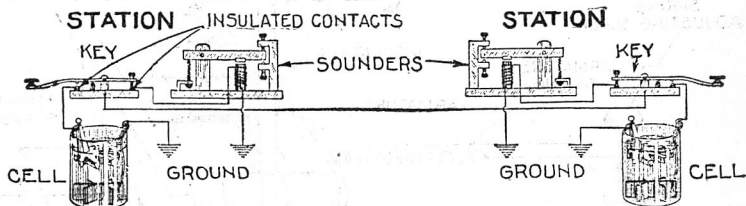


FIG. 7,701.—Elementary diagram showing a simple short line *open circuit* system. In Europe this system is in general use; it consists essentially of so arranging the apparatus that the battery shall only be placed on the line when a message is being transmitted. A main battery is necessary at each station, whereas in the *closed system*, employed in America, main batteries are required only at the terminal stations.

In operation only the battery at the sending station is available, hence twice the battery capacity is required as compared with the closed circuit system. Ordinary keys may be used by insulating the back contact of each.

Relay.—In general, a relay is a device which opens or closes an auxiliary circuit under predetermined electrical conditions in the main circuit.

The object of a relay is to act as a sort of **electrical multiplier**, that is to say, it enables a comparatively weak current to bring into operation a much stronger current.

In so doing it reduces considerably the battery capacity required for a line of given length.

Thus, for a given battery capacity messages can be sent over a much longer line by the aid of a relay; that is, when relays are used, a very weak current will suffice for the main line, since the moving parts of these instruments are very light they require very little energy for operation. The relay controls a comparatively strong local current to operate the sounder.

The essential parts of a relay, as shown in fig. 7,702 are

1. An electro-magnet.

Energized by the main circuit current.

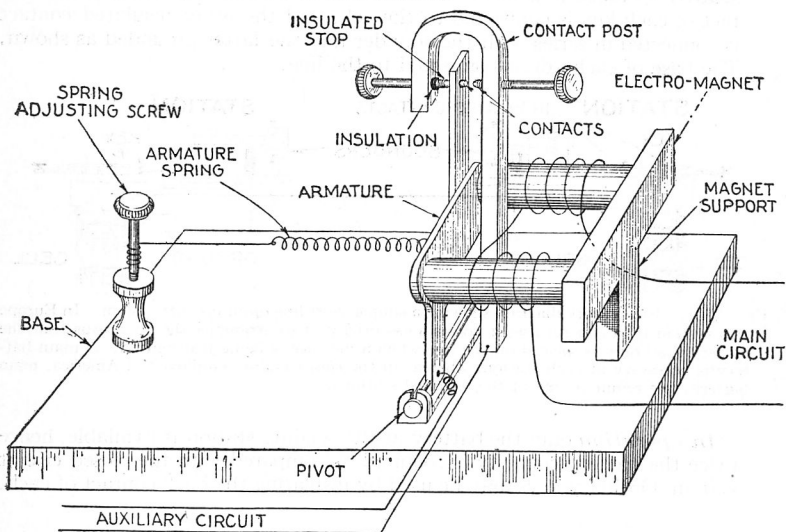


FIG. 7,702.—Elementary relay showing magnet, insulated armature contacts, insulated stop, armature spring, main and auxiliary circuit connections. *The function of a relay is to open or close an auxiliary current under predetermined electrical conditions in the main circuit, so that a comparatively weak current may bring into operation a much stronger current to effect a saving in battery capacity. Note the delicate armature construction as compared with the sounder, thus requiring very little energy to operate. A relay is virtually a very delicate sounder with a contact maker at the end of the armature lever.*

2. An insulated armature.

Very light in construction and pivoted so as to vibrate between a contact and an insulated stop as shown.

3. An adjustable spring.

Designed to hold armature against stop when not attracted by the magnet.

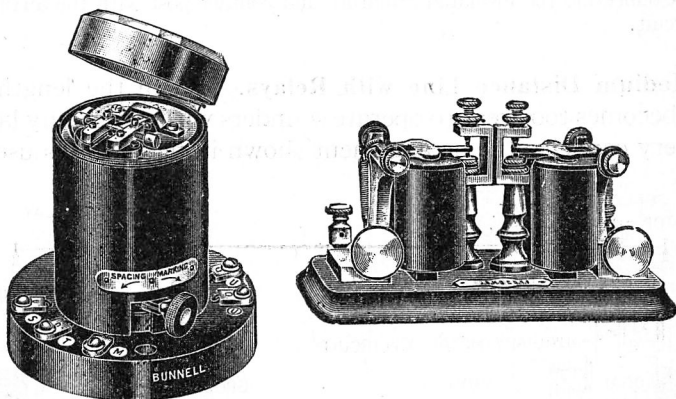


FIG. 7,703.—So called "Wheatstone" or British Post Office *polar* relay. Wound with either two or four windings according to requirements. The two winding form consists of two coils differentially connected in the same manner as the main coils of the four winding type. In the four winding instruments the first set of coils is called the main winding and the second set is called the *accelerating* and *opposing* coils respectively. The main winding consists of two coils each having the same electrical characteristics. Each coil terminates at the binding posts with the letters (U), (D), and U, D. If a jumper be connected from U to (D) and a positive current applied to (U) with its corresponding negative to D the tongue T, or commonly called the armature, will move sharply to contact stop M or marker and if the current be reversed it will move to contact stop S or spacer. Similarly in the four winding type when the opposing coil terminating at OO, and the accelerating coil AA, are connected in series, the same effect will be produced. The normal operating current through the main windings when connected in series is 5 milli-amperes and the minimum operating current is .5 milli-amperes. This instrument is especially useful on high speed automatic telegraph circuits, repeater sets, and on key, worked duplex or quadruplex circuits having small operating margins.

FIG. 7,704.—Bunnell balanced double relay. It consists of two relays connected in series on the same base, having opposite contacts, which may be connected in series or parallel for the purpose of opening or closing a second circuit when the first or main circuit through the relays is varied or broken. As the local contacts are oppositely arranged, that is to break or make circuit under opposing conditions, one making contact on front and the other being properly adjusted, an increase or decrease in the relay circuit will cause one or the other armature to move, thus opening or closing the local or second circuit. This prevents the possibility of alarm being made inoperative by grounding or opening or by increasing or decreasing the current in the circuit.

4. Magnet leads.

Connecting the magnet winding to the main circuit.

5. Insulated armature leads.

Connecting the insulated armature and contact post with the auxiliary circuit.

Medium Distance Line with Relays.—When the length of line becomes too great to operate sounders without unduly large battery capacity the arrangement shown in fig. 7,705 is used.

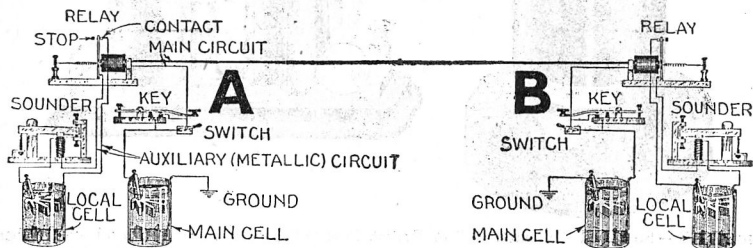


FIG. 7,705.—Elementary short line with relays, showing the main circuit and the auxiliary circuit at each station. The relay, as stated in the text *acts as a sort of multiplier*, that is to say, *it enables the comparatively weak current of the main circuit to bring into operation the much stronger current of the auxiliary circuit to operate the sounder*. On lines of moderate or long distance, as can readily be seen, a considerable saving in battery capacity is effected, by localizing the strong current necessary to operate the sounder, it being understood that considerably more energy is required to operate a sounder than a relay.

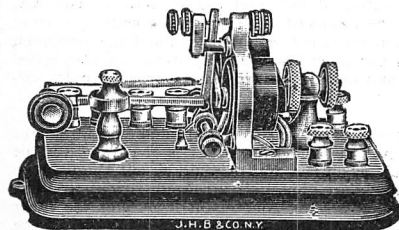


FIG. 7,706.—Smith three coil neutral relay—specially adapted to quadruplex work.

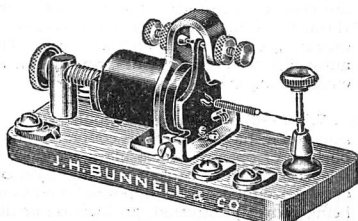


FIG. 7,707.—Bunnell single spool concentric magnet pony relay with adjustable magnet.

It consists of one main circuit and an auxiliary circuit at each station. The main circuit includes the relays, keys, and main cells all connected in series with ground return. The auxiliary circuit at each station is made up of a sounder and local cell joined in series and connected with the auxiliary circuit of the relay as shown.

When not in operation both switches are closed; this energizes the relay magnets and keeps the auxiliary circuits closed by holding the relay contacts together.

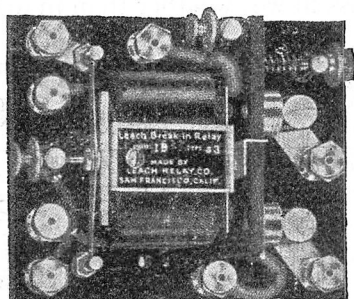


FIG. 7,708.—Bunnell break in relay for rapid handling of traffic working through static, cutting interference to a minimum. You hear what is going on while you are actually transmitting. The receiving operator can stop you at any time by holding his key down for a second and giving you the signal BK. You hear his dash and signal between your own dots and dashes. It operates on 6 volt d.c. and has no external resistance unit. Either a Morse Key, Bug, or Cootie key is used to operate the relay which in turn operates the transmitter.

In operation, the sender opens his switch and with the key sends the message by successively making and breaking the main circuit in proper sequence.

This causes the relay armature to move back and forth against the contact and stop, thus making and breaking the auxiliary circuit in synchronism with the movements of the key. In this way, the very weak main current is enabled to bring into action the much stronger current of the auxiliary or local circuit, thus, the movements of the delicate relay armature are reproduced by the heavy armature of the sounder.

The system shown in fig. 7,705 is suitable for lines not exceeding about 500 miles.

Repeaters.—When the length of a telegraphic circuit exceeds a certain limit, dependent upon the ratio of its insulation to its conductivity resistance, the working margin becomes so small that satisfactory signals cannot be transmitted even by the aid of increased battery capacity. This limit under existing conditions is much less in wet weather than in dry weather.

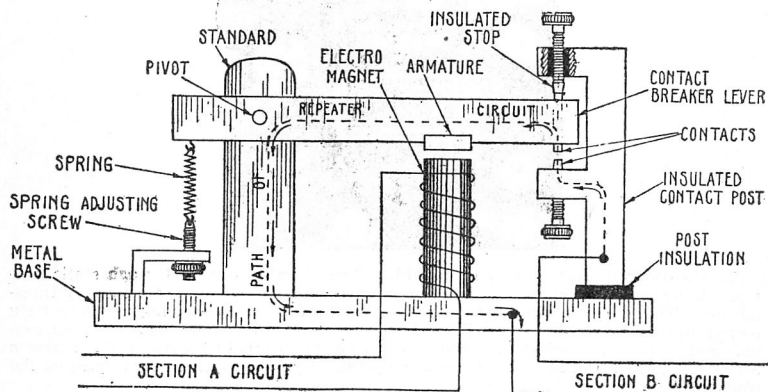


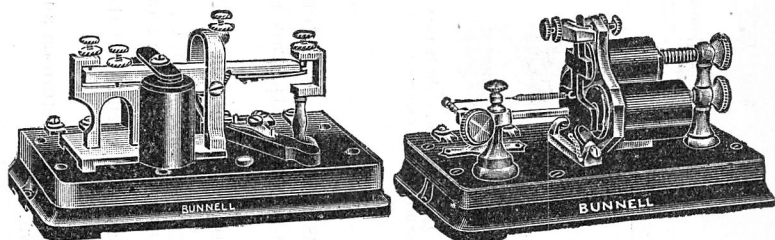
FIG. 7,709.—Elementary repeater showing the insulated parts essential for the contact maker, and path of the current through the repeater portion of the instrument. The insulated stop on the upper arm of the contact post is shown in sectional view to clearly indicate the insulation at this point. Compare this instrument with the elementary sounder fig. 7,696 and note the essential points of difference.

There is no difficulty in directly operating a telegraph of three hundred miles or less, if the line be fairly well insulated and there are not too many offices connected in the circuit. The difficulty arising from the number of offices usually settles itself, since the traffic cannot be handled without great delay when the number of offices is too great, and accordingly, it becomes necessary to employ more wire and divide the offices among them. When, however, the length of a single line increases, the difficulties with *leakage* and *retardation* increase, until the speed and certainty of signaling are

largely reduced. Under such conditions it was formerly necessary to retransmit all communications at some intermediate station, but this duty is now performed by an instrument called a *repeater*.

By definition a repeater is *a sounder provided with a circuit maker for synchronously controlling a second circuit.*

That is to say, it is simply a piece of apparatus in which the sounder (or in some cases the relay), receiving the signals through one circuit, opens and closes the circuit of another line, in the manner that a relay opens and closes the auxiliary circuit of a sounder.



FIGS. 7,710 and 7,711.—Weiny-Phillips automatic repeater set consisting of transmitter fig. 7,710 and relay, fig. 7,711. The third spool of the relay is differentially wound, so that normally the windings neutralize each other and no magnetism is developed in this spool. One of the coils of the differential spool is in circuit with the front contact of the transmitter of opposite side, so that the instant the transmitter circuit is broken the corresponding coil of the differentially wound spool is opened, thereby permitting the second coil to act and hold the relay armature closed. The differential magnet being energized by the breaking instead of the closing of the auxiliary circuits enables this repeater to act quickly, and thereby very materially increases its capacity for rapid signaling.

A repeater as shown in fig. 7,709 consists essentially of *a sounder of the same construction as in fig. 7,696, with the exception that the contact post is insulated and is provided with an insulated stop.* This device forms a contact maker for the repeating section of the circuit.

As indicated by the dotted line and arrows, the path of this circuit is (when closed) through contact post, contacts, contact maker lever, pivot, standard, and out through base.

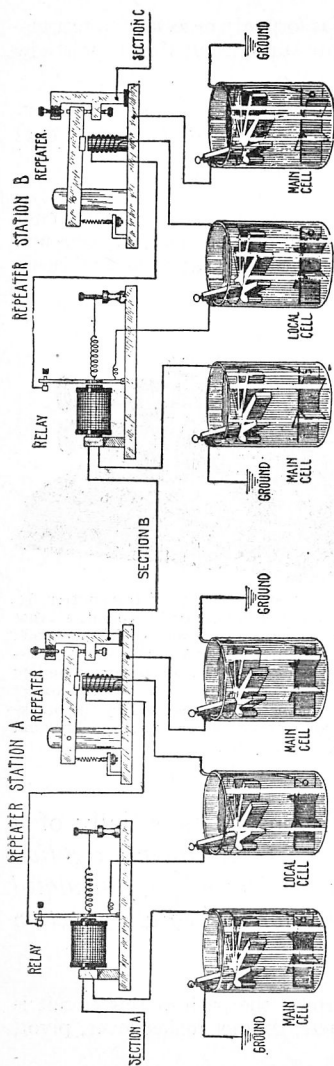


FIG. 7, 712.—Elementary repeaters as connected in a circuit. *In operation*, if the home station or beginning of section A line send a message, the movements of the relay at station A will cause similar movements of the repeater, this in turn is repeated at station B, and all other stations on the line.

Long Distance Repeater Line.—To illustrate how repeaters are used on long distance lines a section of such lines showing two repeater stations is shown in fig. 7, 712.

The figure illustrates how the elementary repeater shown in fig. 7, 709 is connected in the circuit.

As shown, the line is divided into a number of sections, A, B, C, etc., depending upon its length, there being a repeater station joining each section to the preceding one.

The end of section A is connected to the relay main circuit, and the auxiliary circuit to the electro-magnet of the repeater.

There is a ground return on main circuit, and metallic return on auxiliary circuit, one or more cells being included in each of these circuits as shown.

The contact maker circuit of the repeater (which corresponds to the auxiliary circuit of the relay) is connected to section B and ground.

At the end of section B is another repeater station identical with the one just described, and from which section C begins, the number of repeater stations depending on the total length of the line.

An objection to the arrangement shown in fig. 7,712 is that *it will only work in one direction*. This was overcome originally by the button type repeater, and though obsolete now will be described to explain in a very simple way repeater operation.

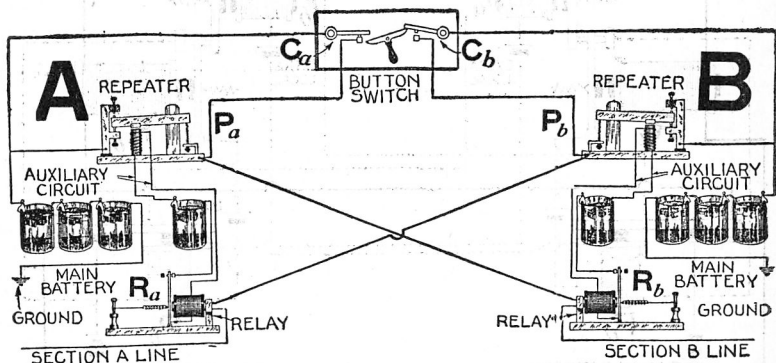


FIG. 7,713.—Diagram showing essentials of the so called button repeater, consisting of two relays, two simple repeaters, a button switch and connections as shown.

The principle of operation of the button repeater is that *the line circuit is extended by making the receiving instrument at the distant terminal of one circuit do the work of the transmitting key of the next circuit, by opening and closing the latter*.

The button repeater comprises *two relays and two simple repeaters, a "button" switch, and connections as shown in fig. 7,713*. For its operation, two local and two main sources of current supply are required.

The button switch provides means for cutting out or closing the circuit around the breaking points of each sounder, otherwise the apparatus would remain unopened.

In the operation of the button repeater if, say, section B, line be opened by the key of the operator, the armature of section B relay will open, which in turn opens section B repeater, whose circuit breaker breaks the circuit of section A. This causes the armature of section A, relay to open, followed by that of section A repeater, the circuit breaker of the latter also breaking the circuit of section A. The operator of section B line cannot now close the circuit, because it is still open in another place, viz., at the circuit breaker of section A repeater. The button switch eliminates this difficulty, for when it is swung to the left, it closes a spring contact C_a , forming a connection between the circuit breaker of section A repeater, enabling the

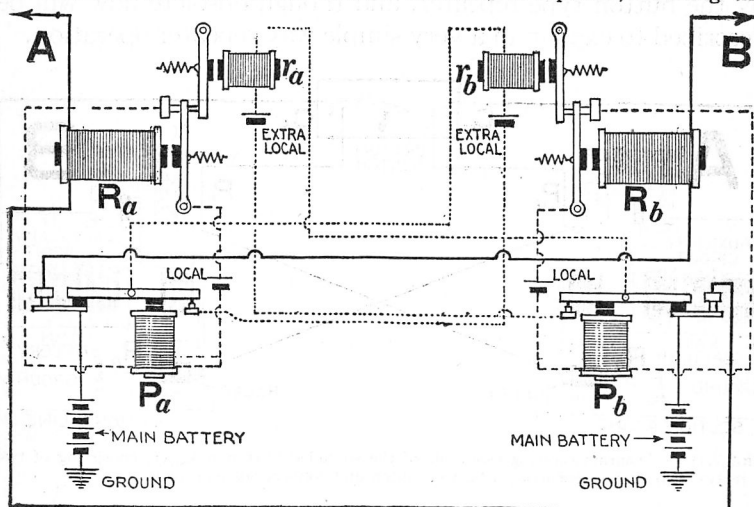


FIG. 7,714.—Milliken repeater system. The relays R_a and R_b are provided with additional or extra magnets r_a and r_b , whose levers press against the main levers in such a manner that when the working current is cut off the working winding, the spring of the extra magnet closes the local contact against the tension of its spring, so that in order that the relay open its local circuit at the local contact, it is necessary that the current be cut off its main line circuit and the current be passing through the local circuit of the extra magnet. The repeaters are provided with two contacts, one, for the local circuit of the opposite extra magnet, and the other, for the closing of the opposite main line circuit. When one of these repeaters opens, its local contact is always broken very shortly before the main line contact is broken, while in closing, the opposite takes place. If section A operator be sending to section B, the incoming signals will be repeated by the tongue of relay R_a . This operates repeater P_a , which in its turn repeats the signals into section B. The repetition of these outgoing signals in the relay R_b , would cause the circuit on the incoming side to open at its local contact, if the extra magnet r_b were not coincidentally demagnetized by the action of the repeater P_a opening the circuit. Accordingly, the outgoing signals cannot disturb the line on the incoming side.

operator of section B to open and close its circuit, at pleasure, while his signals are repeated into section A by the action of the circuit breaker of section A repeater.

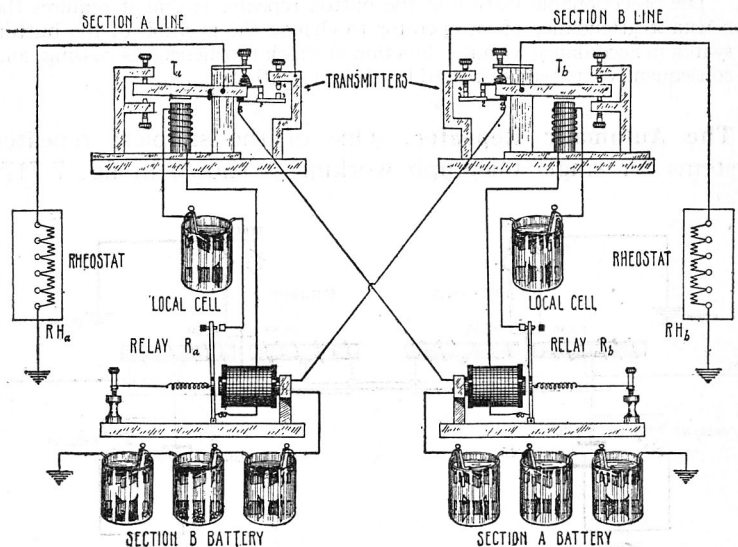


FIG. 7,715.—Diagram of Toye "repeater" or transmitter system, used extensively in the United States and Canada. It comprises two relays, two transmitters with tongue contact breakers, two rheostats and connection as shown. *In operation*, if section B send or open his key, the armature of relay R_a will open as shown, thus opening transmitter T_a lever, which causes contacts 2 and 1 to close and 4 and 3 to open. This change opens section A line, and puts in circuit with relay R_b, section A battery and rheostat RH_a, the resistance of the rheostat being adjusted so that it equals the resistance of section A line. Since this transposition of circuit maintains the current passing through relay R_b at the same strength as before the change of circuit was made, that relay remains closed and likewise also transmitter T_b, thus preserving the continuity of the line while a communication is being sent from section B to section A. Since repeater T_a connects and cuts out section A battery from section A line in response to the operation of relay R_a, relay R_b is prevented opening because section A battery when not in contact with the A line, is given a path to earth through the rheostat RH_a by way of contacts 1 and 2 of transmitter T_a, thus holding relay R_b closed until section A operator desires to "break" or begins sending to section B. In sending from section A to section B a process the reverse of the foregoing holds.

NOTE.—A *disadvantage* of the system shown in fig. 7,715 is the excessive consumption of current, moreover the adjustment of the artificial resistance must be varied to equal that of the line or lines connected through the transmitters, in order to have equal magnetic pull on the relay armatures whether the relay be in circuit with the artificial line or the main line.

The button repeater is called a *manual repeater* as distinguished from the *automatic type*.

The objectionable feature of the button repeater is that it requires the constant attendance of an operator to change the position of the button switch in accordance with the direction in which the message is passing, and consequently has been displaced by the automatic type.

The Automatic Repeater.—One of the simplest repeater systems for single telegraph working is shown in fig. 7,717.

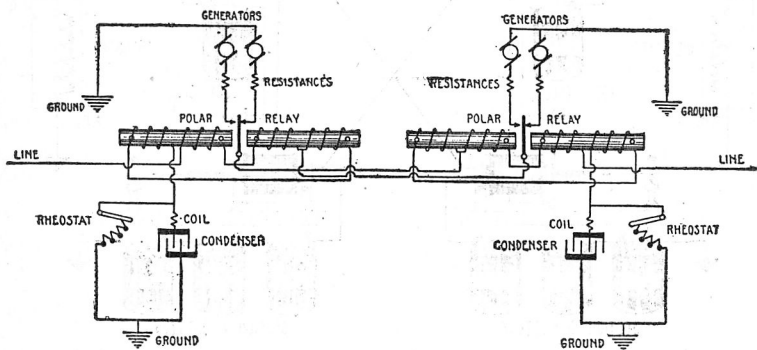


FIG. 7,716.—Diagram of the Postal telegraph repeater system. The Postal direct point duplex repeater is an arrangement by which the respective armature levers of two polar relays at the repeater office connect the positive and negative main battery currents direct to the line wires. Its principle is represented diagrammatically in the figure. The armatures of both polar relays are closed when a distant office closes the key, as shown in the diagram. This results in placing the duplex negative battery in contact with the other line. As the current passes through the coils differentially, the armature of the open line will not be affected by the impulse thereof. When the closed key is opened the positive battery is presented to the line.

This repeater consists of a *transmitter* having a second lever placed above the regular armature lever in such a position that one electro-magnet is employed to work both.

There are three distinct pairs of circuits:

1. Main. 2. Local. 3. Shunt.

In the operation of this repeater (shown in fig. 7,717) when a key on the western circuit is opened the instruments assume the positions shown in the diagram.

The armature of relay R^1 , first falls back and opens the local circuit of transmitter T^1 , which in turn opens the eastern circuit at $s^1 r^1$, thus causing the armature of relay R to fall back.

This falling back of the armature of relay R , however, does not affect the local circuit of transmitter T , because before the eastern circuit was broken at $s^1 r^1$, the shunt around the local contacts of relay R was closed at $M^1 O^1$.

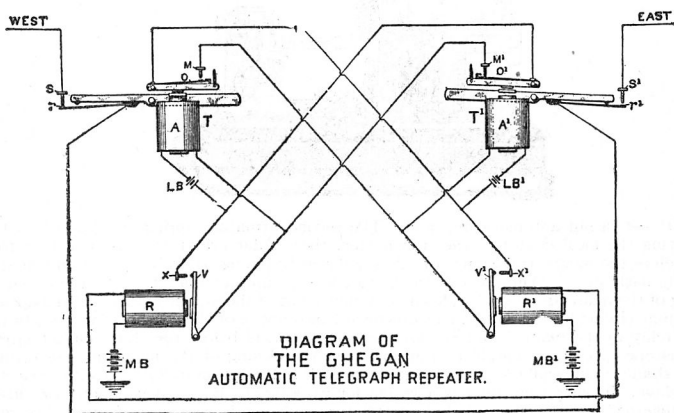


FIG. 7,717.—Diagram of Ghegan automatic repeater. Its principle of operation is based upon the fact that an armature, on being drawn toward a magnet becomes itself magnetic by induction, and that the closer it approaches the magnet core, the stronger the magnetism becomes. The circuits and operation are further explained in the accompanying text.

On closing the western key, the armature of relay R^1 closes the local circuit of transmitter T^1 , which in turn first closes the eastern circuit at $s^1 r^1$, and, as already explained, after sufficient time has elapsed to permit the armature of relay R to reach its front stop, opens the shunt circuit of transmitter T at $M^1 O^1$.

Should east "break" when west is sending, the armature of relay R would remain on its back stop, thus breaking the local circuit of transmitter

T, on the first downward stroke of the superposed armature of transmitter T¹, and so break the western circuit at s r.

There being no extra weight or attachment of any kind to either the relay or transmitter armatures, the quickest possible action can be obtained with this repeater. As both *relay armatures* work in *unison*, it can always be seen at a glance if the signals are being *properly repeated*.

The transmitters are provided with switches for working the lines independently or putting them together at will.

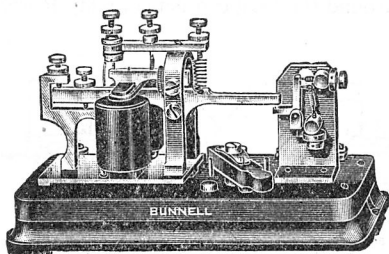
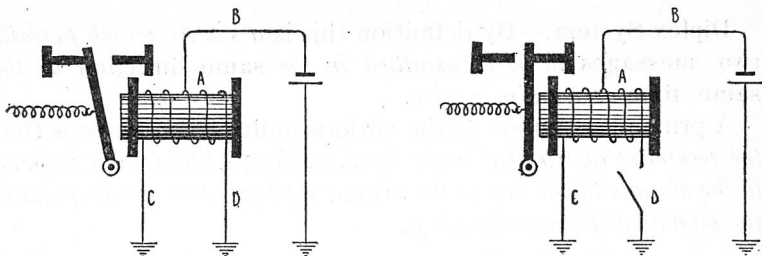


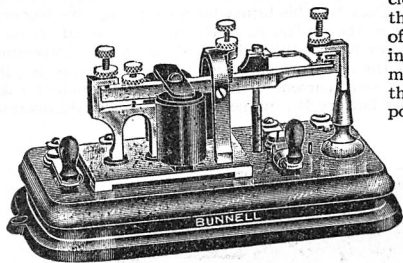
FIG. 7,718.—Ghegan automatic repeater. The second armature spring is adjusted so that on closing the local circuit of the transmitter, the regular armature must reach its front stop before the magnetism induced in it is sufficiently strong to draw the second armature from its back stop. The object of this is to allow a sufficient margin of time between the closing of the main circuit by the downward movement of the first armature and the opening of a shunt circuit by the subsequent downward movement of the second armature, to permit a relay in the main circuit to close its local contacts before the shunt circuit around them is opened. This margin of time between the closing of the main and the opening of the shunt circuit enables these repeaters to work well even on leaky lines with very sluggish relays. This transmitter has a switch for working the lines independently or putting them together at will. The fact that an armature on being drawn toward a magnet becomes itself magnetic by induction, and that the closer it approaches the magnet the stronger the magnetism becomes, are the novel principles utilized in this repeater.

Half Repeaters or Side Line Apparatus.—When a single line and a duplex circuit are expected to repeat into each other, one half of the apparatus of any of the previously described types of single line repeaters, slightly modified, may be employed.

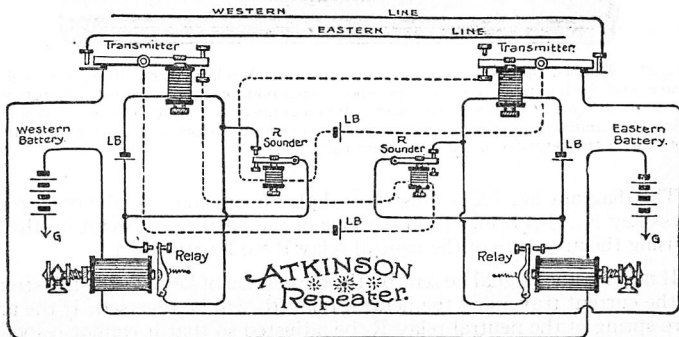
In order to avoid confusion with the full set, however, they are called respectively the “Half-Milliken,” the “Half Weiny,” the “Half-Atkinson,” etc., according to the type.



FIGS. 7,719 and 7,720.—Detail of the differentially wound third spool of relay of the Weiny-Phillips system. In fig. 7,719, one terminal of the battery is shown grounded while the other terminal is shown connected differentially with two equal windings of the magnet. The current divides at A, half going through each coil. It may be observed that the direction of the winding of one coil is opposite to that of the other. Thus, when current flows through the wire B, the magnetization of the core due to the action of current in the coil A-C is neutralized by the presence of current in the coil A-D and as a result the core is not magnetized at all; so that the retractile spring attached to the armature holds the latter in the "open" position as shown in fig. 7,719. If, however, while the coil A-C remains closed, the coil A-D be opened, as in fig. 7,720, the core will be magnetized due to the presence of current in the coil A-C while no current exists in coil A-D, the latter no longer neutralizing the magnetic effect of the former. The armature, therefore, is attracted and held in the "closed" position as shown in fig. 7,720.



FIGS. 7,721 and 7,722.—Atkinson repeater transmitter and diagram, used by the Western Union. The repeater set consists of two standard relays, two Atkinson Transmitters and two repeating sounders arranged as shown in the diagram.



Diplex System.—By definition this is a system which permits two messages to be transmitted in the same direction at the same time over a single wire.

A principle common to the various multiplex systems is that the receiving instrument at the home station, while free to respond to the signals of the key at the distant station, shall not respond to the signals of its associate key.

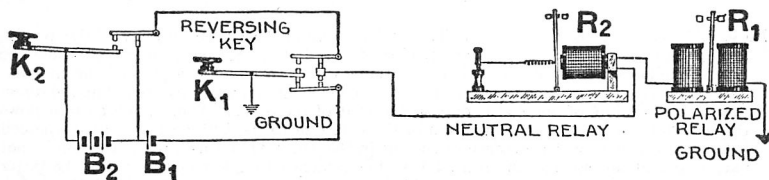


FIG. 7,723.—Elementary diplex system; diagram illustrating the principle of diplex telegraphy. *In operation*, if the sender depress key K_2 , this brings both sections of the battery in circuit on the line, causing the armature of the neutral relay R_2 , to be attracted. If now another signal be sent by the depression of key K_1 , the full strength of the current traversing the neutral relay R_2 , will be reversed. If the armature spring of the neutral relay R_2 , be adjusted so that it cannot respond to the weak current of battery B_1 , it is evident that signals may be sent by reversing the smaller battery B_1 , by means of K_1 , which will operate R_1 , but not R_2 .

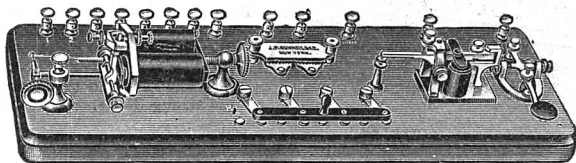


FIG. 7,724.—Bunnell open circuit automatic repeater. A relay, transmitter, key, lightning arrester and switch mounted on a polished hardwood base constitutes one instrument. Two of these make a complete repeater. When connected they can be used as an automatic open circuit repeater or as two single sets of ordinary Morse open circuit instruments, according to the position of the switch on each set.

The diagram fig. 7,723 illustrates diplex operation. If the operator depress key K_2 , this brings both sections of the battery in circuit on the line, causing the armature of the neutral relay R_2 to be attracted.

If now another signal be sent by the depression of key K_1 , the full strength of the current traversing the neutral relay R_2 will be reversed. If the armature spring of the neutral relay R_2 be adjusted so that it cannot respond to

the weak current of battery B_1 it is evident that signals may be sent by reversing the smaller battery B_1 by means of K_1 , which will operate R_1 but not R_2 .

The principle and operation of polarized relays is explained in the accompanying cuts.

Duplex System.—This system is one which permits *the sending of two messages simultaneously in opposite directions over a single wire*.

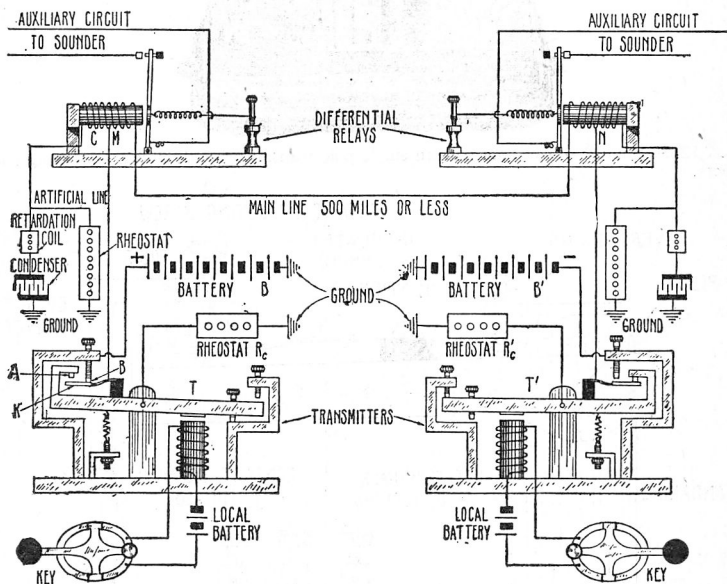


FIG. 7,725.—Stearn's differential duplex system. The circuit can be traced from the tongue contact K , to the point of division M , known as the "split." At this point one branch goes through the right portion of the relay winding to the main line, and the other through the left portion of the relay, the artificial line and to ground. When K , is in contact with B , the circuit is through battery B , to ground, and when in contact with A , it is through the transmitter lever, and rheostat R_c , to ground. The purpose of the rheostat R_c , is to divide the current passing through the relay coils equally between the main and artificial lines. When this condition is established, the current will pass through the relay with no appreciable effect upon it and the duplex is said to be "balanced."

There are several systems of duplex telegraphy, namely:

1. Differential;
2. Polar $\left\{ \begin{array}{l} \text{with battery;} \\ \text{with dynamo;} \end{array} \right.$
3. Bridge.

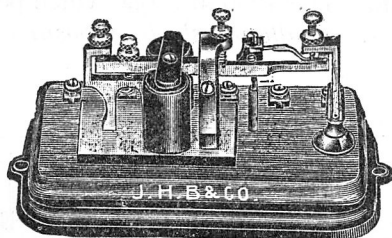


FIG. 7,726.—Bunnell shovel nose pattern single pole transmitter with circuit preserving contacts.

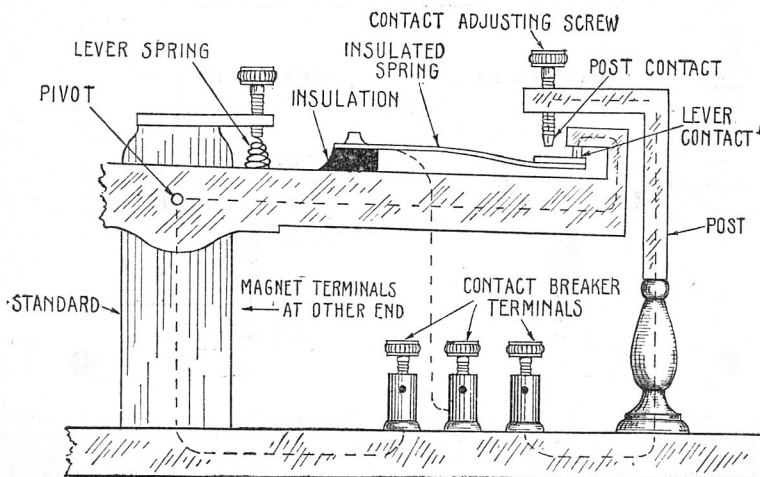


FIG. 7,727.—Detail of contact breaker end of a transmitter showing the three contacts, method of mounting the spring contact, and the circuits from the contacts to terminals. The duration of contact, or portion of the stroke of lever during which the circuit through the post contact and spring contact remains closed is regulated by the contact adjusting screw. This adjustment and other construction details are clearly shown in the illustration.

Differential Duplex System.—This method employs a relay wound with two sets of coils, in each of which the current flows in a different direction.

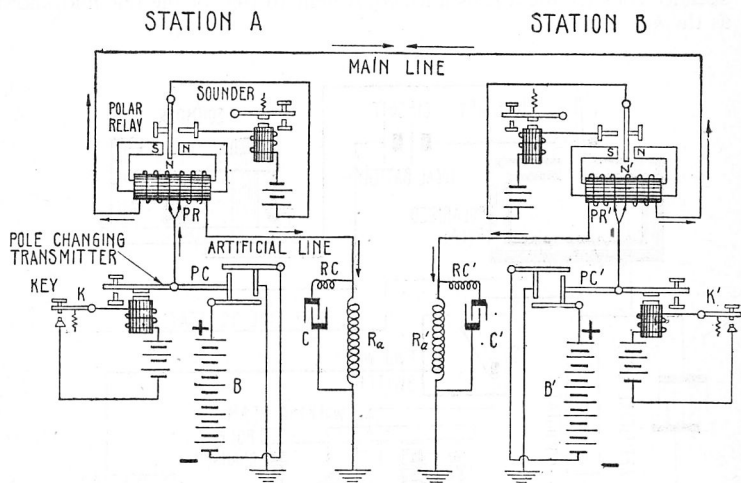


FIG. 7,728.—The battery polar duplex system. When the resistance of the main line is balanced by the resistance of a set of adjustable coils in the rheostat R_a of the artificial line, the current will divide into two equal parts at the polarized relay, and passing around the cores in different directions will neutralize each other and thus fail to magnetize the relay. This is called the *ohmic balance*. The *static balance* is effected by neutralizing the static discharge on the line by shunting the rheostat R_a , by means of an adjustable condenser C and a retarding coil RC .

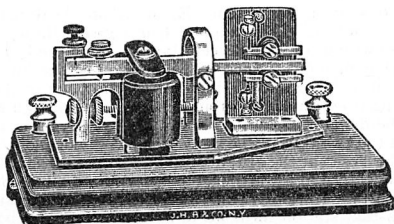


FIG. 7,729.—Bunnell W. U. battery (or gravity) pole changer for duplex or quadruplex work.

Consequently when two currents of equal intensity are passed through the relay at the same time, they neutralize each other, and the relay does not become magnetized.

Each station is provided with a differential relay, and there are two complete circuits, one including the line wire, and the other consisting of resistance coils having a resistance equivalent to that of the line and known as the *artificial line*.

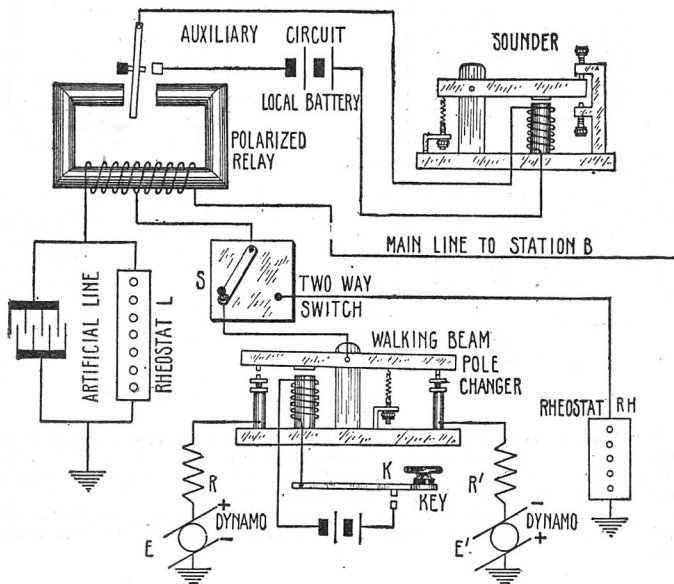


FIG. 7,730.—The dynamo polar duplex system. E. and E' are the dynamos, E for the positive and E' for the negative current. These supply their currents through resistance coils R R' either of German silver wire or of incandescent lamps. K is the key which closes the local circuit of the walking beam pole changer. The position of the lever of the pole changer determines which current is being sent to line through the pivot of the lever. The two way switch S is for changing from duplex to ground connection through a rheostat RH for the purpose of enabling the distant station to obtain a balance. From the switch the current goes to the junction of the two coils of the relay where it divides, one-half going to the main line, if the line circuit be closed at the distant station, and the other half through the artificial line to ground. The resistance in the artificial line is made equal to the resistance of the line and relay coils at the distant station. This is adjusted, not by measurement, but by trial. The operator at the distant station turns his switch to the ground position and signals are then sent by the operator at the home station.

The key and battery at each station are common to both circuits, the points of divergence being at the relay and at the ground plate.

When the key at one station which may be called the *home station* is depressed, the current flows through both sets of coils of the relay at that station without producing any magnetizing effect. Consequently, the relay and sounder at the home station remain unresponsive, but at the distant station the current will flow through only one set of coils at that station and will cause it to operate the local sounder. The same effect, of course, is produced when the key of the distant station is depressed.

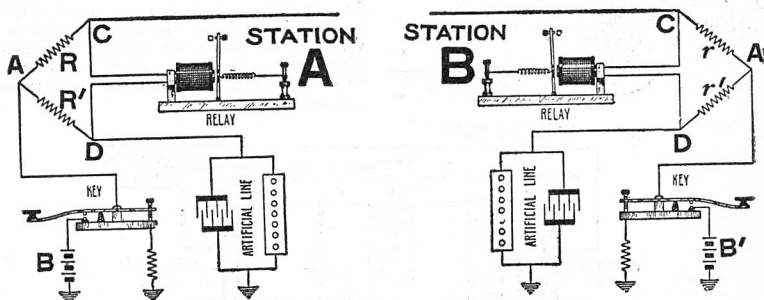


FIG. 7,731.—Diagram illustrating the operation of the bridge duplex system. In the figure, B and B', are the main line batteries, one at each station. R, R', and r, r', are the bridge resistances at each station. The various connections are clearly shown in the diagram. **In operation**, closing station A key sends out a current which divides at A, half passing over the main line to station B, and reaches earth via the apparatus at that end of the line, while the other half passes through the artificial line at station A, reaching the earth at that end of the circuit. Since the resistance between C and D, is the same as R or R', the pressures at C and D, are equal, and no current will flow through station A relay. This holds only when the resistance of station A artificial line is made equal to the resistance of the actual line to ground at the distant end. The relay at A is accordingly not affected when A sends to B. The same condition obtains when B alone sends to A. Signals from A operate the relay at B because the incoming signals have a joint path made up of the branches CD and CA, thus setting up a difference of pressure between the points C and D sufficient to operate the relay.

Polar Duplex System.—Each station is *provided with two batteries or dynamos, which are arranged in such a manner that the direction of the current in the line depends on whether the key is in its raised or depressed position.*

As in the case of the differential method, the current divides at the relay, which instead of being of the differential type is known as a *polarized relay*.

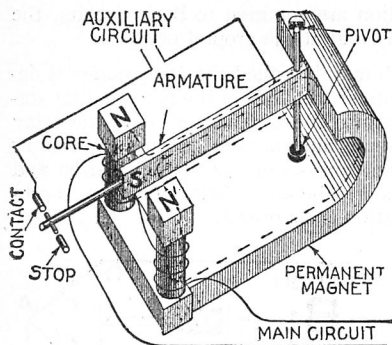


FIG. 7,732.—Elementary polarized relay. *In operation*, when no current flows through the electro magnet, the armature (having no spring), when placed midway between the poles of the electro magnet will be attracted equally by each and accordingly will approach neither. When, however, the electro magnet is energized, the magnetism thus reduced in its cores either increases or overcomes that due to the permanent magnet producing unlike poles according to the direction of the current. Thus the armature is attracted by one and repelled by the other. The magnetism of the electro magnet of the polarized relay changes in response to the reversals of the distant battery and the armature vibrates to and fro between its front and back stops in accordance with those changes.

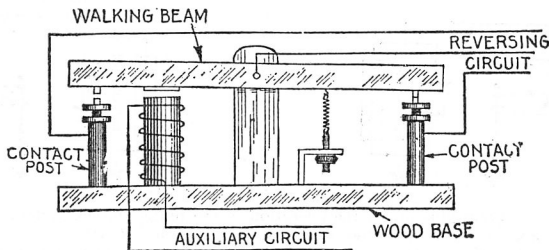


FIG. 7,733.—Essential parts of a walking beam type pole changer. As can be seen it is impossible for all three wires of the reversing circuit to be connected at any instant, that is before each reversal, the circuit is broken, thus interposing an air gap; this is an undesirable condition where dynamos are used for current supply, because their very small internal resistance would otherwise permit considerable sparking.

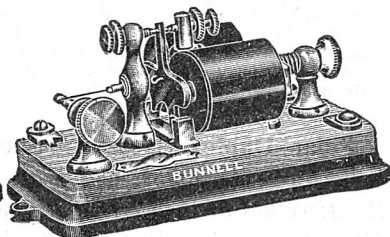
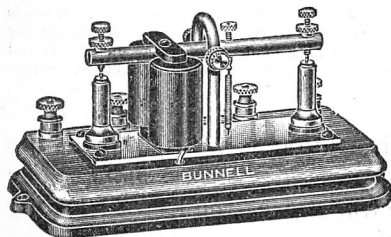


FIG. 7,734.—Standard dynamo pole changer walking beam model for duplex and quadruplex circuits.

FIG. 7,735.—Bunnell pony pole changer. Penn. R. R. pattern for dynamo work in duplex and quadruplex circuits.

Bridge Duplex System.—This method is based on the principle of the **Christie** or so-called Wheatstone bridge. It is used in the operation of submarine telegraph cables.

In this method, the relay is placed in the cross wire of a Christie bridge and the key is so arranged that connection is made with the battery before the line leading to the earth is broken. Adjustable resistance coils are placed in the arms of the bridge and a wire connects the key with one arm of the bridge, which is completed at the opposite end by a suitable arrangement.

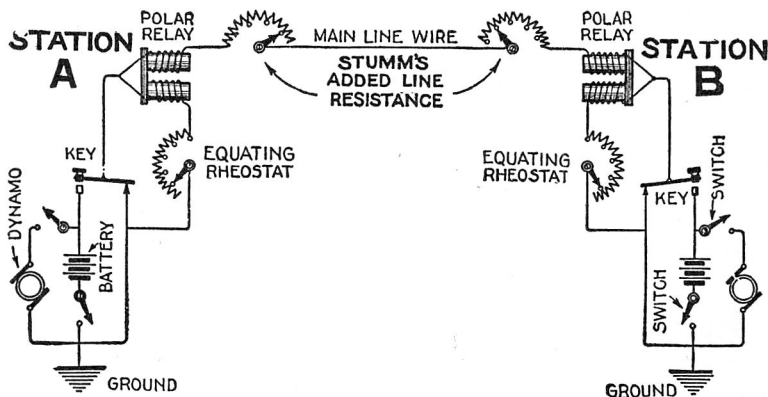


FIG. 7,736.—Frank A. Stumm's added adjustable line resistance. Necessary in duplex and all other multiplex office equipment. Formerly all balancing against wet weather line leakage was done on the artificial line rheostat and was always very unsatisfactory and often entirely ineffectual so that quite frequently such circuits had to be abandoned until the weather resumed normality—that is, became dry. The Stumm method leaves the artificial rheostat stand unchanged at normal ohmage, *i.e.*, equal to the actual line resistance in dry weather and when the wet storm begins to cause leakage, line resistance is looped in between the relay and line sufficient to balance the artificial ohmage, and by being added to sufficiently as required maintains a steady working balance reversing the procedure as the storm recedes. This method not only secures a good and continuous working balance but also prevents heating of instrument and other office wires and cables because the resistances in the main and artificial lines remain the same in stormy wet weather as during fair and dry. In other words the actual and artificial lines have flowing in them the proper battery strength for the resistances traversed. The value of the Stumm line resistance is very great as it prevents damaging delay to tens if not hundreds of thousands of telegrams during every general rain storm which inevitably occurred under the old method of wet weather balancing. The relays used may be differential, if preferred.

If the resistances be equal, the relays will not operate when the current is transmitted, but since the earth is employed to complete the circuit, they

will respond to the received current, thus enabling each operator to send and receive signals at the same time.

Quadruplex System.—This method of telegraphy permits the simultaneous sending of two messages in either direction over a single wire.

Theoretically it consists of an arrangement of two duplex systems, which differ from each other so greatly in their principles of operation that they are capable of being used in combination.

The sending apparatus consists of a reversing key and a variable current key (or equivalent), and the receiving apparatus consists of a neutral relay and a polar relay, batteries and connections.

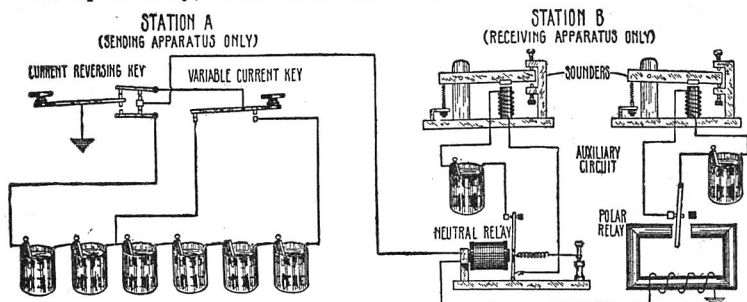
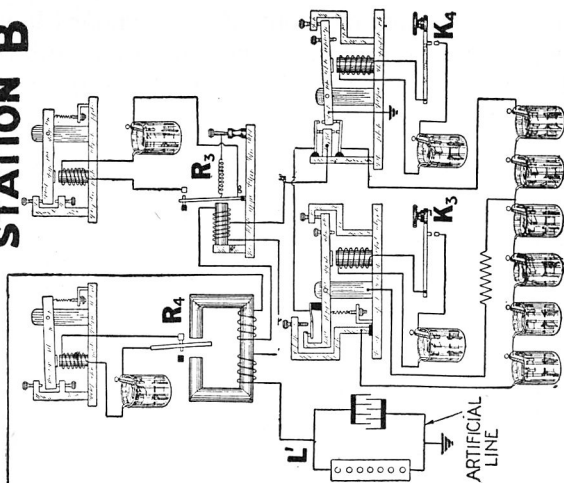


FIG. 7,737.—Elements of the quadruplex system. For simplicity, the receiving apparatus is omitted at station A and the sending apparatus at station B, the complete installation being shown in fig. 7,738. Because of the fact that a polar relay responds solely to changes in direction of the current, and a neutral relay to changes in strength of the current, it must be evident that, if the two relays be connected in series as shown, signals may be produced by the polar relay by operating the current reversing key, and with a sufficiently weak current the neutral relay will not respond; also, if the *direction* of the current be maintained constant by using the variable current key signals will be produced on the neutral relay but not on the polar. Hence, with this arrangement, two messages may be sent from station A to station B simultaneously, and by extension, if the reader imagine each station fitted with both sending and receiving apparatus, four messages may be sent at one time, thus giving quadruplex operation.

Typebar Tape Teletype Printing Telegraph System.—The teletype machine is a simple intercommunicating machine for interchanging messages between two or more points.

NOTE.—The tape machine prints on a narrow strip of paper. The page machine prints on a wide sheet of paper usually 8½ ins. wide. The automatic sending machine provides for sending from a perforated strip which acts as a storage medium for the message.

STATION B



STATION A

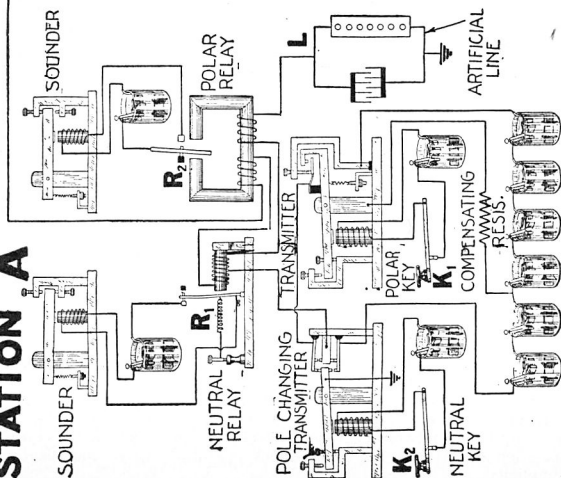


FIG. 7,735.—Quadruplex system with battery current supply. The apparatus employed in operating the polar system of the duplex is generally called the "No. 1 side of the system," or the polar side. It consists of the polar key and the polar relay at either station. The apparatus employed in operating the other system of the duplex is called the "No. 2 side of the system," or the neutral side. It consists of the neutral key and of the neutral relay. *In operation*, when none of the keys is depressed, no current flows through the line, but a comparatively feeble current flows through the artificial lines L and L', insufficient to operate the neutral relays, and to maintain the polarized relay tongues on the dead stops. Consequently, none of the sounders responds. If now K₁ be depressed, a strong positive current is sent to line at station A. This does not affect the relays at A, since it passes through them in opposite directions but, on arriving at B, it tends to keep the polarized relay tongue R₄ on the dead stop, while it has sufficient power to operate the neutral relay R₃. In the same way if K₃ alone be depressed, relay R₁ alone will respond. If

Fig. 7,739 illustrates the arrangement of the standard keyboard, together with a representation of the code combinations for each character as they appear in the perforated strip used with automatic sending machines.

In this system the Morse key and code are replaced by a keyboard similar to that of the ordinary typewriter, but the results obtained by depressing the keys on the teletype keyboard however, are quite different. By depressing the keys, various electrical signals are sent out over a wire or wires and these electrical signals cause corresponding characters to be printed on a narrow ribbon of paper, both at the home and distant stations. With the commercial typewriter, the key levers operate the type bars mechanically.

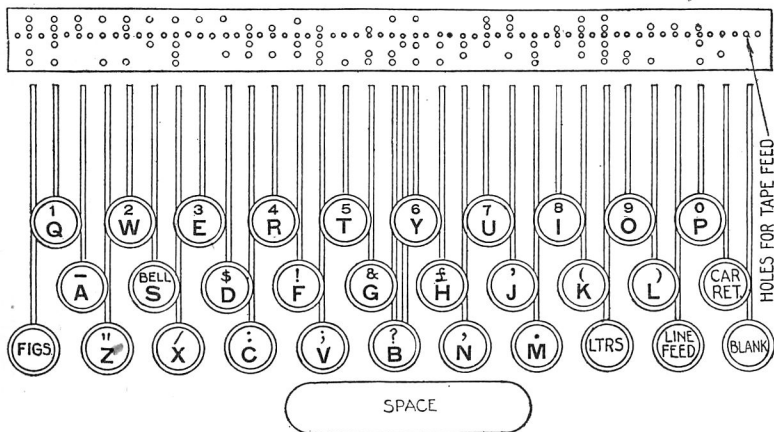


FIG. 7,739.—Teletype keyboard and corresponding code combination.

FIG. 7,738.—Text continued.

K_2 alone be depressed, a feeble negative current will flow to line, in a direction which will actuate R_4 , but it will not have sufficient power to actuate R_3 . If K_4 alone be depressed R_2 alone will similarly respond alone. The depression of any key will cause its corresponding relay to close its local circuit at the distant end of the line, regardless of the condition of the keys at that end. In practice the reversed position of neutral relay stop requires a repeater with contact on the up stroke between each neutral relay and sounder, or the equivalent secured by transposition of battery, for synchronous operation; these modifications are here omitted for simplicity.

The key levers on the teletype, however, are not connected mechanically to the type bars, but send out electrical signals which control the type bars, both at the home and distant stations.

Since the key levers are not connected mechanically to the type bars, the teletype may be divided into two units:

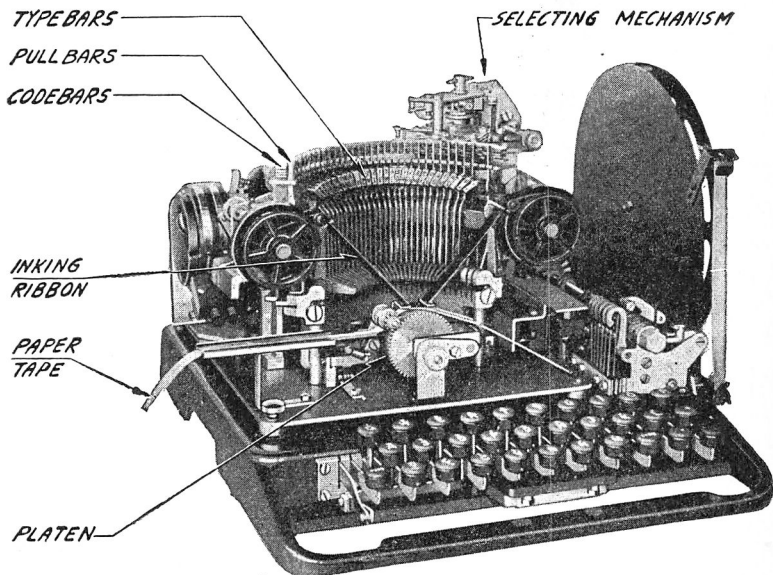


FIG. 7,740.—Teletype machine. The printing unit translates into printed characters the signals sent out by the transmitter. The various characters are on type bars which are caused to strike the paper tape as it is pulled over a narrow platen. The balance of the mechanism serves only to properly select the various type bars, move the tape forward, move and reverse the inking ribbon as on a standard typewriter, and shift the platen for upper case characters. At the bottom in the center is the platen over which the paper tape passes from right to left. Immediately above the platen is the inking ribbon. The type bars are plainly visible just back of and above the platen, arranged in a semi-circle and striking downward. Just above and back of the type bars are the code bars, five in number, and semi-circular in shape. The pull bars are just in front of the code bars and one is pulled into the notches in the code bars when the notches are lined up for that particular letter. When the selecting mechanism lines up the notches in the code bars and the proper pull bar is pulled into the notches, the operating bail is released and moves upward. The operating bail engages a notch in the pull bar pulling the latter upward, thus causing the type bar to print that particular letter.



1. Keyboard transmitter (lower portion);

2. Printing unit (upper portion).

The keyboard transmitter is the instrument *which sends out the various character signals to one or more teletypes.*

FIG. 7,741.—Teletype five unit code. *The diagram shows* graphically the intervals or impulses of each combination of the code. Each horizontal row represents the complete unit of time, during each of the five intervals of which current may be transmitted or omitted. The black spots represent current and the white ones no current. Thus, in the case of the letter E, current is sent during the first interval and no current during the remaining four intervals. The letter R, requires current during the second and fourth intervals and no current during the first, third and fifth intervals. Each combination of signals is preceded by a *start* and followed by a *stop* signal, the functions of which are explained in the note below.

NOTE.—*The tape machine* is very popular for a communication service in which the individual communications are short, do not require more than one copy and need not be kept on file for any great length of time. However, if so desired, the tape can be pasted on a blank to give the appearance of a page message. *The page machine* is found to be very satisfactory for longer communications which are kept for future reference, for making multiple copies, and in some cases for handling special forms. From the point of view of handling telegraph traffic, the page system is not quite so efficient, because the signals controlling the operations of feeding the paper and of returning the carriage to the beginning of each line have to be transmitted over the circuit by the sending operator. These operations are not required with the tape printer. Machines for sending from a perforated strip find their use where a large volume of traffic is to be handled as in press offices. The message in the perforated strip form will pass through the sending mechanism or transmitter at a regular rate, say 360 characters per minute, but the operator in preparing the message in this form for transmittal can exceed this speed and, therefore, have a freedom of working which is found to be quite desirable. This uniform speed of transmitting over the circuit corresponds with the fastest working of most operators who are employed to prepare the perforated strip.

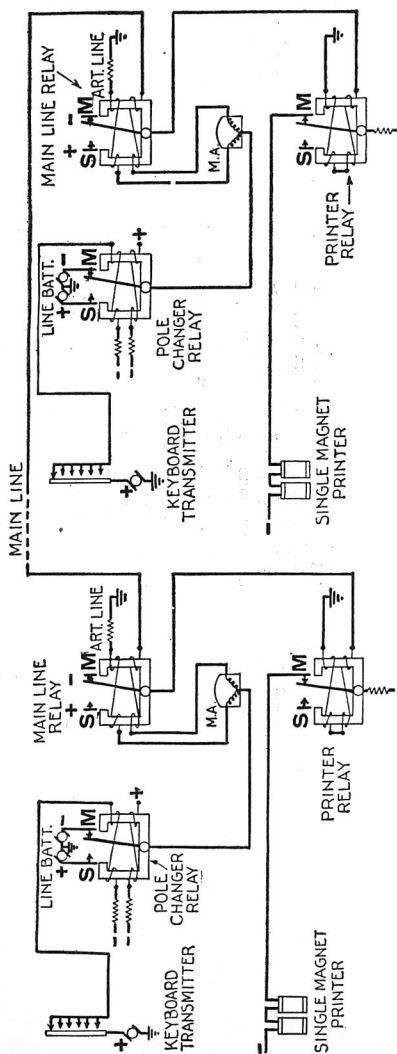


FIG. 7,742.—Two keyboard teletypes connected for duplex operation. The keyboard contacts are connected to one winding (operating winding) of the pole changer relay. Current is connected to the other winding (holding winding) in a manner that will cause the relay tongue to move to the spacing side when the keyboard contacts are open. When the keyboard contacts are closed a current of twice the value is sent through the operating winding in the opposite direction which will overcome the magnetic effect of the holding winding and cause the relay tongue to be moved to the marking side. The contacts of the pole changer relay are connected to marking and spacing battery. The tongue goes to the split of the main line relay where the circuit divides. One path of the current is through one winding of the relay to the line wire and the other path is through the second winding of the relay through the artificial line to ground. As the tongue of the main line relay responds to the distant signal it operates the printer relay, the printer relay in turn will send make-break signals to the receiving printer magnet.

One motor drives both the keyboard transmitter and printing unit. It consists of a bank of properly lettered key levers, a set of notched selector bars, a contact mechanism, and a clutch, through the medium of which the contact operating mechanism is driven.

The printing unit furnishes a home record of the matter sent, and also serves as a receiver when another station is transmitting.

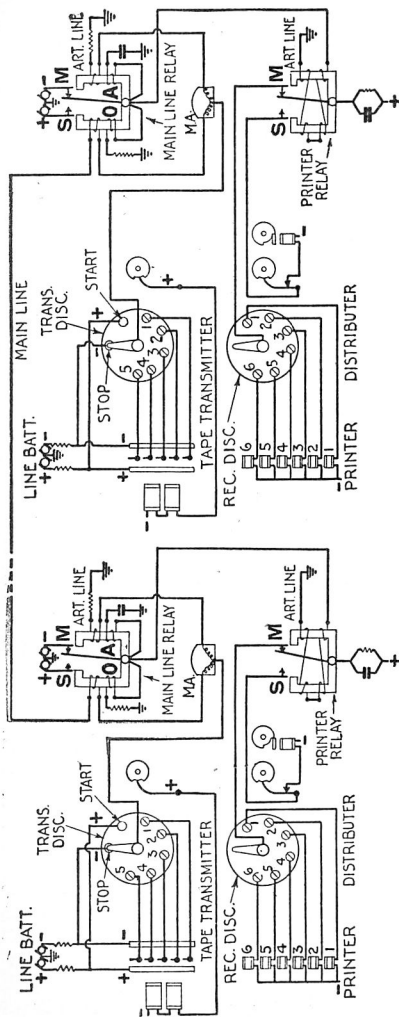


FIG. 7,743.—Theoretical circuit of two tape transmitter sets connected for duplex operation. The main line relays have in addition to the usual operating windings two auxiliary windings, O and A. These auxiliary coils in conjunction with a condenser and resistance, are connected in such a manner as to set up a steady vibration of the main line relay armature when not under the influence of the current flowing through the operating windings. With this circuit the speed of operation of the relay is greatly increased. *In operation* when the tongue reaches the spacing contact, a rush of current passes to the condenser through the accelerating winding A, in such a direction as to hold the tongue against the spacing contact. At the same time the current flows through the opposing winding O, and a resistance in series with it in such a direction as to tend to move the tongue toward the marking contact giving an opposing effect to the current in the accelerating and operating windings. The condenser charging current, however, diminishes to zero, while the current to the opposing winding increases to a steady value which will cause the tongue to move toward the marking contact when the line current diminishes at the moment of reversal. As soon as the tongue leaves the spacing contact, battery is cut off and the condenser discharges through the accelerating and opposing coils in a direction to assist the motion of the tongue, thus shortening the transit time. When the tongue reaches the marking contact, the same cycle of operation is repeated, the tongue, of course, tending to move in the reverse direction.

It is entirely mechanical with the exception of a pair of magnets which assist in translating the electrical signals sent to the teletype. Printing is effected by means of type bars which move forward and downward, instead of backward and upward as with the commercial typewriter. Ink is supplied to the paper tape by means of a ribbon in the usual way.

The signaling code employed to transmit the characters is known as *the five unit code*.

If a given unit of time be divided into five intervals, during each of which current may or may not be transmitted, it is possible to produce thirty-two different combinations of current and of no current intervals.

Duplex Teletype Printer Operation.—By use of duplex apparatus it is possible to transmit in both directions **simultaneously over a single wire**.

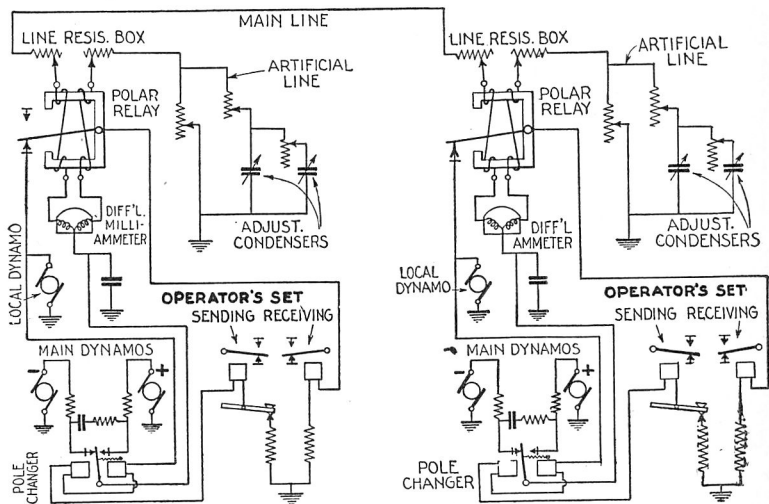


FIG. 7,744.—Teletype circuit diagram for duplex operation showing entire artificial line.

NOTE.—Teletype unison. The start signal and the stop signal cause the printing units to revolve in unison with the transmitter so that the character signals sent out by the transmitter may be translated into letters and other characters by the printing unit. The transmission of the start impulse allows the selector magnet armature to operate the trip mechanisms on the printing units and the selector cams start to revolve. The speed of rotation is such that when the cam shaft of the transmitter has revolved far enough to send out the first impulse, the printing unit shaft has revolved to the proper position to receive it. When the transmitter has revolved to the position to send out the second impulse, the printing unit shaft will have also rotated to the proper position to receive it. At the end of the revolution the transmission of the stop impulse attracts the selector magnet armature and the selector cams are stopped by the stop pawl.

Each printer terminal set consists of a tape transmitter, a transmitting receiving disc type distributor, a receiving printer, a main line relay, a printer relay and the artificial line apparatus. Where circuits are to be composed compositing equipment is made part of the set.

Fig. 7,742 shows two keyboard teletypes connected for duplex operation. Inasmuch as only make break signals can be sent from the keyboard contacts it is necessary to use a pole changer relay so that polar signals may be sent to the line.

The arrangement of the entire artificial line is shown in fig. 7,744.

TEST QUESTIONS

1. *Of what does the simplest form of telegraph consist?*
2. *Give a classification of telegraph systems.*
3. *What is a key?*
4. *Describe the construction of a key or transmitting instrument.*
5. *What is a sounder?*
6. *Describe the construction and operation of a sounder.*
7. *Draw a diagram showing, a, open circuit short line system; b, closed circuit short line system.*
8. *What is a relay?*
9. *Describe the construction and operation of a relay.*
10. *Name the different types of relay and describe each.*

11. *Draw a diagram of a medium distance line with relays.*
12. *Describe the operation of a medium distance line with relays.*
13. *What is a repeater?*
14. *Describe the construction and operation of a repeater.*
15. *How are repeaters used on long distance lines?*
16. *Explain the Milliken repeater system.*
17. *What is an automatic repeater?*
18. *Explain the three pairs of circuits in an automatic repeater.*
19. *What is a half repeater?*
20. *Describe the duplex system.*
21. *How does a duplex system work?*
22. *What kind of a relay is employed in the differential duplex system?*
23. *Draw a diagram of the dynamo duplex polar system.*
24. *Explain the operation of a polarized relay.*
25. *How does a walking beam pole changer work?*
26. *Upon what is the bridge duplex system based?*
27. *Describe in detail the quadruplex system.*
28. *Explain the operation of the typebar tape teletype printing telegraph system.*
29. *Explain duplex teletype printing operation.*

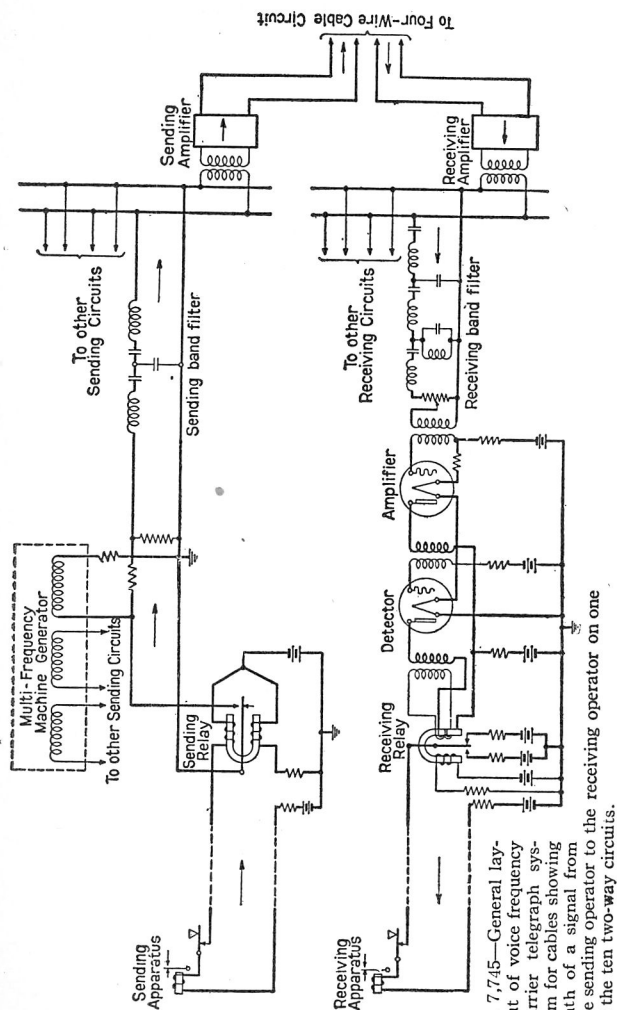


FIG. 7,745.—General layout of voice frequency carrier telegraph system for cables showing path of a signal from the sending operator to the receiving operator on one of the ten two-way circuits.

THE WESTERN ELECTRIC COMPANY

FRESHEST EGGS AT BOTTOM MARKET PRICES

SHE IS HIS SISTER.

FIG. 7,746.—Test message transmitted over New York-Horta cable with a high speed siphon recorder, at a speed of 1920 letters per minute, November 14th, 1924.

CHAPTER 190

Optics

As a preliminary to taking up the study of motion pictures the student should have a general knowledge of optics.

By definition, optics is *that part of physics which deals with the property of light*.

Various explanations have been made as to: *What is light?* The most important of these are the emission or corpuscular theory, and the undulatory or wave theory.

The emission theory assumes that luminous bodies emit, in all directions, an imponderable substance which consists of molecules of an extreme degree of tenuity. These are propagated in right lines with an almost infinite velocity. Penetrating into the eye, they act on the retina and produce a sensation which is called *vision*.

The undulatory theory assumes that all bodies, as well as the celestial spaces are filled with an extremely subtle elastic medium, called the luminiferous ether, the luminosity of a body being due to an infinitely rapid vibratory motion of its molecules, which, when communicated to the ether, is propagated in all directions in the form of spherical waves, and this vibratory motion, being thus transmitted to the retina, produces the sensation called *vision*.

Definitions

Image.—The appearance of an object at a place where no object exists.

Real Image.—The image formed when the rays actually meet.

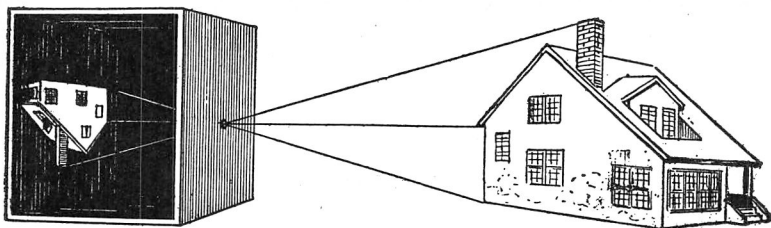


FIG. 7,747.—Image produced by small aperture showing the crossing of luminous rays at the aperture causing inversion of the image.

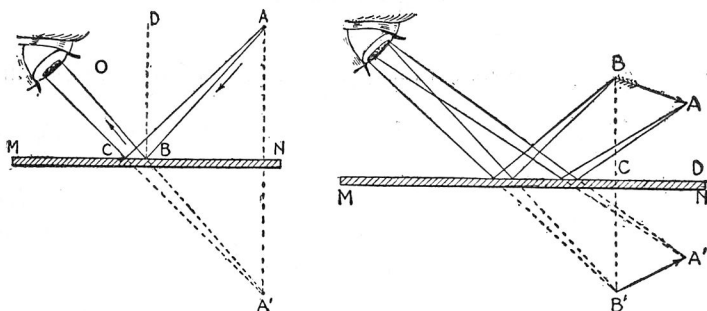


FIG. 7,748.—Formation of images by plane mirrors. The determination of the position and size of image resolves itself into investigating the images of a series of points. CASE I: *Single point A placed in front of a plane mirror*, as in fig. 7,748. Any ray AB, incident from this point on the mirror is reflected in the direction BO, making the angle of reflection DBO equal to the angle of incidence DBA. If a perpendicular AN, be let fall from the point A over the mirror, and if the ray OB, be prolonged below the mirror until it meets this perpendicular in the point A', two triangles are formed, ABN and BNA', which are equal, for they have the side BN common to both, and the angles ANB, ABN, equal to the angles A'NB, A'BN; for the angles ANB and A'NB are right angles, and the angles ABN and A'BN are each equal to the angle OBM. From the equality of these triangles, it follows that A'N is equal to AN; that is, that any ray AB, takes such a direction after being reflected, that its prolongation below the mirror cuts the perpendicular AA' in the point A', which is at the same distance from the mirror as the point A. This applies also to the case of any other ray from the point A, as AC. It follows, that all rays from the point A, reflected from the mirror, follow after reflection, the same direction as if they had all proceeded from the point A'. The eye is deceived, and sees the point A at A', as if it were really situated at A'. Hence, in plane mirrors, *the image of any point is formed behind the mirror at a distance equal to that of the given point, and on the perpendicular let fall from this point on the mirror.*

FIG. 7,749.—Formation of images by plane mirrors. CASE II: *Object AB placed in front of the mirror*, as in fig. 7,749. The image of any object will be obtained by constructing the image of each of its points, or at least, of those which are sufficient to determine its form. Fig. 7,749 shows how the image A'B' of any object AB is formed.

Virtual Image.—The image formed when the rays only appear to meet.

Mirror.—A polished surface which reflects objects placed before it.

Production of Images.—When luminous rays, which pass through a small aperture into a dark chamber, are received upon a screen, they form

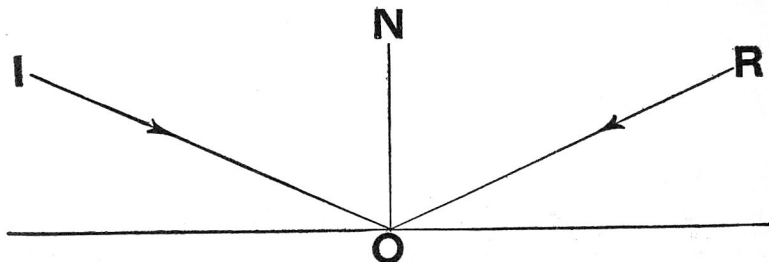


FIG. 7,750.—Angles of incidence and reflection. LAW: *The angle of reflection is equal to the angle of incidence.* The ray IO is called the incident ray; OR, reflected ray; angle ION, angle of incidence; angle NOR, angle of reflection; NO, normal or perpendicular to the reflecting surface.

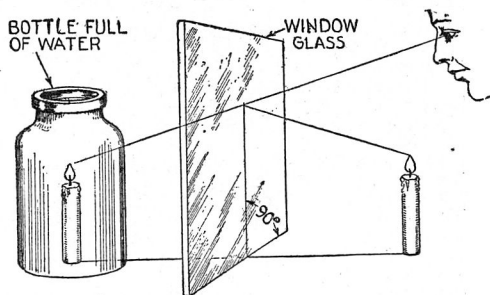
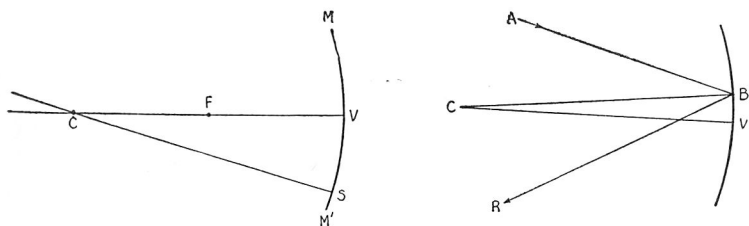


FIG. 7,751.—Position of image in a plane mirror. Let a candle be placed exactly as far in front of a pane of window glass as a bottle full of water is behind it, both objects being on a perpendicular drawn through the glass. The candle will appear to be burning inside the water. This experiment explains a large number of familiar optical illusions, such as "the figure suspended in mid-air," "bust of person without trunk," "stage ghost," etc. In the last case the illusion is produced by causing the audience to look at the actors obliquely through a sheet of very clear plate glass, the edges of which are concealed by draperies. Images of strongly illuminated figures on one side appear to the audience to be in the midst of the actors.

images of external objects as shown in fig. 7,747. These images are inverted because the luminous rays proceeding from external objects, and penetrating into the chamber, cross one another in passing the aperture as shown in fig. 7,747.



FIGS. 7,752 and 7,753.—Concave spherical mirror; explanation of fig. 7,750 V, vertex; MM', the aperture; CV, the principal axis; CS, a secondary axis; C, center of curvature; F, principal focus (midway between V and C). Any line drawn from C to the mirror will be perpendicular to the mirror at that point. This line then will always be the normal which will be used in making the angle of incidence equal to the angle of reflection. Now in fig. 7,753, if AB be an incident ray of light, the angle ABC is the *angle of incidence*. To find the direction of the reflected ray draw BR so that the angle CBR equals angle ABC, then will BR be the direction of the reflected ray.

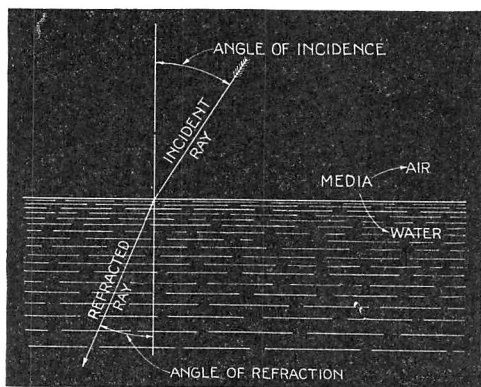


FIG. 7,754.—Diagram illustrating refraction definitions. All the light which falls on a refracting surface does not completely pass into it; one part is reflected and scattered, while the other penetrates into the medium. According to the *undulatory theory*, the most highly refracting media is that in which the velocity of propagation is least. In uncrystallized media, such as air, liquids, ordinary glass, the luminous ray is singly refracted; but in certain crystallized bodies, such as Iceland spar, selenite, etc., the incident ray gives rise to two refracted rays. The latter phenomenon is called *double refraction*.

Reflection.—The change of direction experienced by a ray of light, or of other radiant energy, when it strikes a surface and is thrown back or reflected, as shown in fig. 7,750.

Laws of Reflection.—1. *The angle of reflection is equal to the angle of incidence.* 2. *The incident and the reflected rays are both in the same plane which is perpendicular to the reflecting surface.*

Refraction.—The change of direction which a ray of light undergoes upon entering obliquely a medium of different density from that through which it has been passing, as in fig. 7,754.

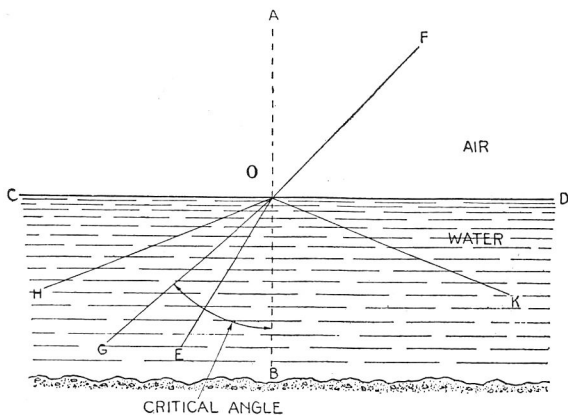


FIG. 7,755.—Diagram illustrating the critical angle or that angle between the incident ray and the perpendicular drawn to the surface in the medium of smaller velocity at the point at which total reflection begins to occur. In the diagram let CD be a surface separating two transparent media, the lower one being the denser of the two (as air and water). If a ray EO, strike the surface it will be bent away from the normal AOB, along the line OF, in accordance with the law of refraction $\sin AOF = \mu \sin EOB$. If now the angle EOB be increased, AOF, will go on increasing until $\sin AOF = 1$, and the refracted ray passes along OD; in this case the ray in the dense medium makes an angle BOG, with the normal such that $\mu \sin BOG = 1$, from which, $\sin BOG = 1 \div \mu$. This angle BOG is the critical angle.

Index of Refraction.—The ratio between the sines of the incident and refracted angles. It varies with the media, for instance from air to glass it is $\frac{3}{2}$; from air to water, $\frac{4}{3}$, sometimes called *refractive index*.

Laws of Refraction.—1. *Light is refracted whenever it passes obliquely from one medium to another of different optical density.* 2. *The index of refraction for a given substance is a constant quantity whatever be the angle of*

incidence. 3. The refracted ray lies in the plane of the incident ray and the normal. 4. Light rays are bent toward the normal when they enter a more refractive medium, and from the normal when they enter a less refractive medium.

Lenses.—A lens may be defined as, a piece of glass or other transparent substance with one or both sides curved. Both sides may be curved, or one curved and the other flat.

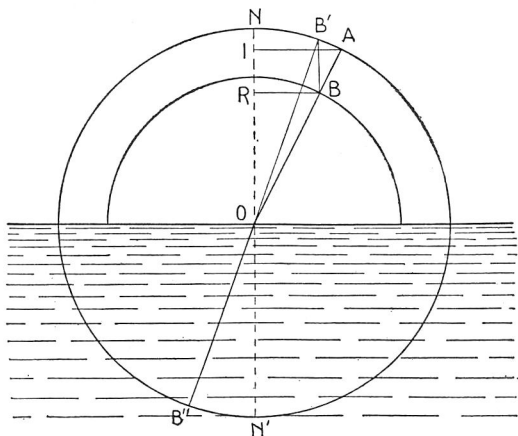


FIG. 7,756.—Construction of refracted ray. Let AO be a ray of light passing through air and entering water at O. The index is $\frac{4}{3}$. Draw two circles with centers at O and with radii whose lengths are as 4 : 3. Draw AI and BR perpendicular to the normal NN'. Since AO : BO = 4 : 3, then AI : BR = 4 : 3. Hence if AI be the sine of the angle of incidence, BR is the sine of the angle of refraction. If then, BB' be drawn parallel with the normal, and a straight ruler be placed on the points B' and O, the line OB', the refracted ray may be drawn.

The object of a lens is to change the direction of rays of light, and thus magnify objects, or otherwise modify vision.

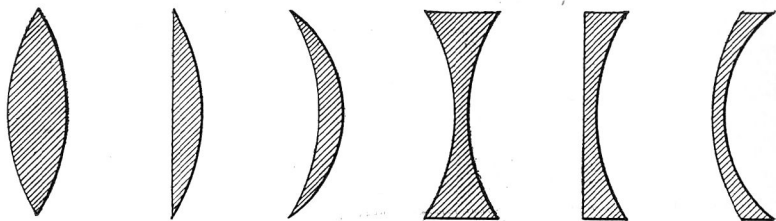
There are various kinds of lens and they may be classed as:

1. Convex.

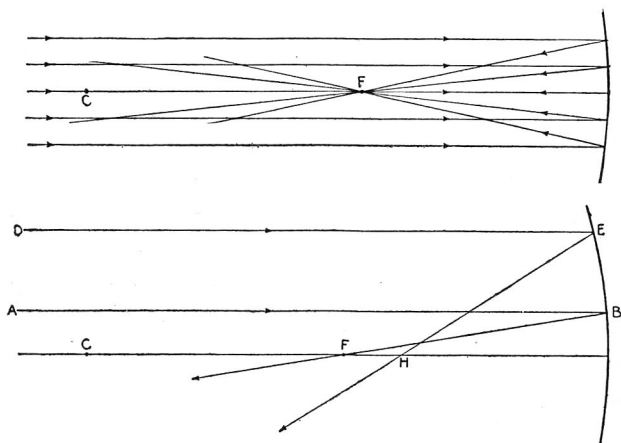
- a. double convex;
- b. plano convex;
- c. concavo convex.

2. Concave.

- a. double concave;
- b. plano concave;
- c. Convex concave.



FIGS. 7,757 to 7,762.—Various lenses. *The first three* are thicker at the center than at the borders, and are called *converging*; *the second three*, which are thinner at the center are called *diverging*. In lenses whose two surfaces are spherical, the centers of these surfaces are called centers of curvature, and the right line which passes through these two centers is the principal axis. In a plano-concave or plano-convex lens, the principal axis is the perpendicular let fall from the center of curvature of the spherical face on the plane face.



FIGS. 7,763 and 7,764.—The principal focus. *By definition*, it is that point where all the rays *parallel* with the principal axis meet after reflection, as, for instance, the rays from a source of light at an infinite distance from the mirror. The sun is so far distant that its rays are practically parallel. When they are reflected upon a concave mirror they are reflected to the principal focus F; forming a point of intense light and heat.

These various types of lens are illustrated in figs. 7,757 to 7,762, which give a better idea of the numerous combinations of curved and plane surfaces than is obtained by definition.

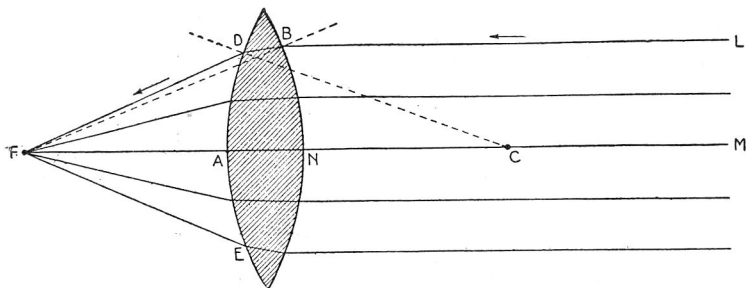


FIG. 7,765.—Principal focus in double convex lens. CASE I: *Rays from luminous sources parallel with the principal axis.*

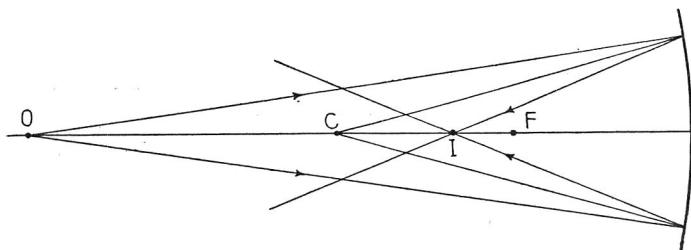


FIG. 7,766.—Conjugate foci. *By definition*, when two points are so related that object and image may exchange places, they are called *conjugate foci*. If a luminous object be placed at the point O, it projects divergent light rays upon the mirror. These rays will focus at a point I, a little further from the mirror than the principal focus F. If the source of light be now placed at I, the rays will pass back over the same paths and will come to a focus at O; the points I and O thus related to each other are called *conjugate foci*. Concave mirrors make divergent rays less divergent, parallel or convergent; parallel rays, convergent; convergent rays more convergent.

Foci in Double Convex Lenses.—*The focus of a lens is the point where the refracted rays, or their prolongations meet.* Double convex lenses have both real and virtual foci.

Principal Foci.—Fig. 7,765 shows the case in which the luminous rays which fall on the lens are parallel with its principal axis.

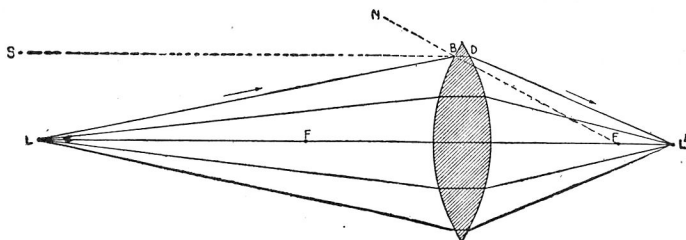


FIG. 7,767.—**Principal focus** in double convex lenses. CASE II: *Divergent rays from luminous source.* In the figure the luminous source being at L, by comparing the path of a diverging ray LB, with that of a ray, SB, parallel with the axis, the former is found to make with the normal, an angle LBN, greater than the angle SBN, hence, after traversing the lens, the ray cuts the axis at a point L', which is more distant than the principal focus F. As all rays from the point L intersect approximately in the same point L', this latter is the conjugate focus of the point L. This term has the same meaning here as in the case of mirrors, and expresses the relation existing between the two points L and L', which is of such a nature that, if the luminous point be moved to L', the focus passes to L.

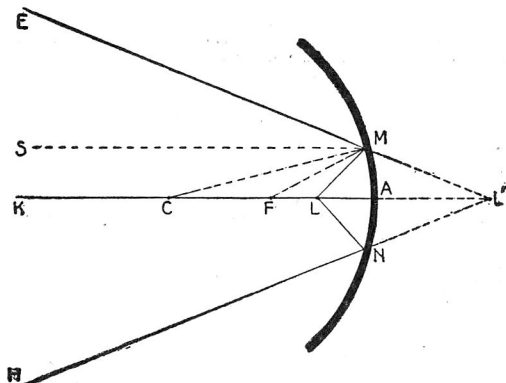


FIG. 7,768.—**The virtual focus.** If a source of light be placed at L, between the principal focus F, and the mirror, any ray LM emitted from L, makes with the normal CM, an angle of incidence LMC, greater than FMC. The angle of reflection must be greater than CMS, and therefore the reflected ray ME diverges from the axis AK. This is also the case with all rays from the point L, and hence these rays do not intersect, thus forming no conjugate focus. If they be regarded as being prolonged on the other side of the mirror, their prolongations will intersect in a point L', on the axis, giving the same effect to the eye as though the rays were emitted from the point L', this point being called the *virtual focus*.

Fig. 7,767 shows the case in which the luminous source is outside the principal focus, but so near that all incident rays form a divergent pencil.

Virtual Foci.—A double convex lens has a virtual focus when the luminous object is placed between the lens and the principal focus, as shown in fig. 7,769.

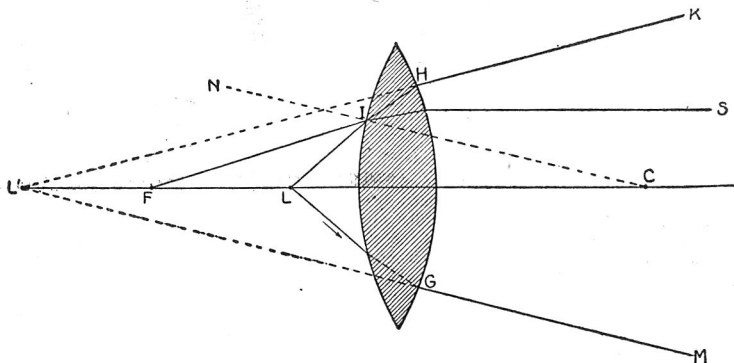


FIG. 7,769.—Virtual focus in double convex lens. In the figure, L is the position of the luminous source between the principal focus and the lens; F is the principal focus, and L', the virtual focus corresponding to the position L of the luminous source.

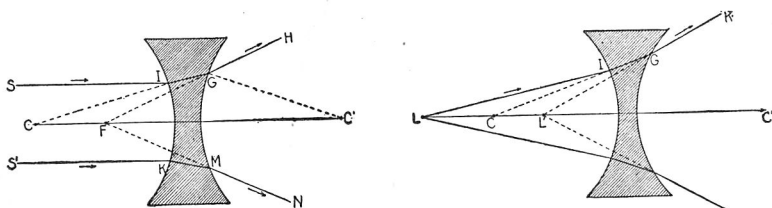


FIG. 7,770.—Virtual focus in double concave lens. CASE I: *Parallel incident rays.* Let SS' be any pencil of ray parallel with the axis. Any ray SI is refracted at the point of incidence I, and approaches the normal CI. At the point of emergence it is also refracted, but diverges from the normal GC', so that it is twice refracted in a direction which moves it from the axis CC'. Since the same conditions obtain for every other ray, S'KMN, it follows that the rays, after traversing the lens, form a diverging pencil, GHMN. Hence, there is no real focus, but the prolongations of these rays cut one another in a point F, which is the principal virtual focus.

FIG. 7,771.—Virtual focus in double concave lens. CASE II: *Divergent incident rays.* In this case where the rays radiate from a point L on the axis, it is found by the same construction that a virtual focus is formed at L', which is between the principal focus and the lens.

In this case the incident rays make with the normal greater angles

than those made with the rays FI from the principal focus. Accordingly, when the former rays emerge, they move farther from the axis than the

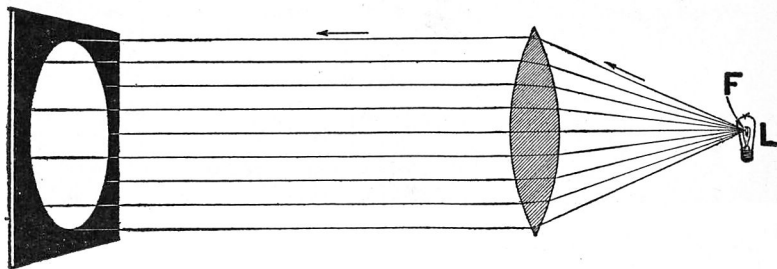


FIG. 7,772.—Effect of placing luminous source at the principal focus of a double convex lens. As the point of light comes near the lens, the convergence of the emergent rays decreases, and the conjugate focus L' (fig. 7,767) becomes more distant. When the source of light L coincides with the principal focus F , as shown above, the conjugate focus is at an infinite distance, that is to say, the emergent rays are parallel. When this condition obtains, the intensity of light decreases slowly, thus, a small lamp can illuminate a considerable distance.

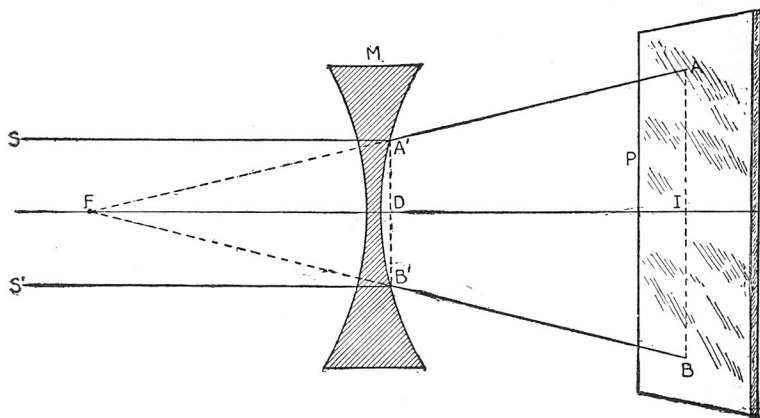


FIG. 7,773.—Experimental determination of the principal focus of a double concave lens. The face AB is covered with an opaque substance, such as lamp black, two small apertures, A and B , being left in the same principal section and at an equal distance from the axis. A pencil of sunlight is then received on the other face, and the screen P , which receives the emergent rays, is moved toward or away from the lens until A and B , the spots of light from the small apertures, are distant from each other by twice $A'B'$. The distance DI is then equal to the focal distance FD , because the triangles $FA'B'$ and FAB are similar.

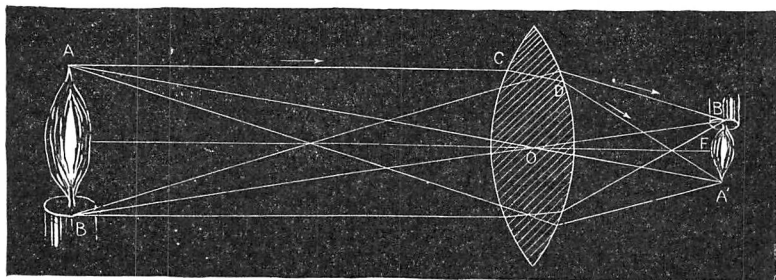


FIG. 7,774.—Formation of real image by double convex lens. Let AB be placed beyond the principal focus. If a secondary axis AA' be drawn from the outside point A , any ray AC from this point will be twice refracted at C and D , and both turning in the same direction, approaching the secondary axis, which it cuts at A' , the other rays from the point A will intersect in the point A' which is accordingly the conjugate focus of the point A . If the secondary axis be drawn from the point B , it will be seen that the rays from this point intersect in the point B' , and as the points between A and B have their foci between A' and B' , a real and inverted image of AB will be formed at $A'B'$. To see this image it may be received on a white screen, on which it will be depicted, so the eye may be placed in the path of the rays emerging from it. Again, if $A'B'$ were the luminous object, its image would be formed at AB .

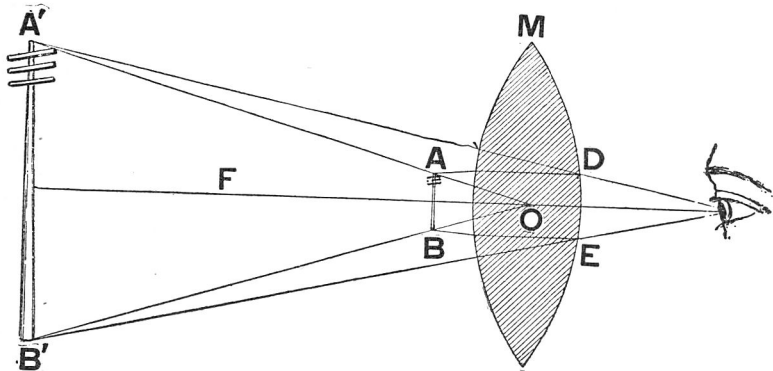


FIG. 7,775.—Formation of virtual image by double convex lens; object AB , placed between the lens and its principal focus. If a secondary axis OA' be drawn from the point A , every ray AD , after having been twice refracted, diverges from this axis on emerging, since the point A is at a less distance than the principal focal distance, this ray, continued in an opposite direction, will cut the axis OA' in the point A' , which is the virtual focus of the point A . Tracing the secondary axis of the point B , it will be found in the same manner, that the virtual focus of this point is formed at B' . There is, therefore, an image of AB at $A'B'$. This is a virtual image; it is erect and larger than the object. The magnifying power is greater in proportion as the lens is more convex, and the object nearer the principal focus.

latter, and form a diverging pencil HK, GM. These rays cannot produce a real focus, but their prolongations intersect in some point L' , on the axis, and this point is the virtual focus of the point L .

Foci in Double Concave Lenses.—In lenses of this form, *there are only virtual foci*, whatever be the distance of the object. See figs. 7,770 and 7,771.

Formation of Images by Double Convex Lenses.—In lenses as well as in mirrors, *the image of an object is the collection*

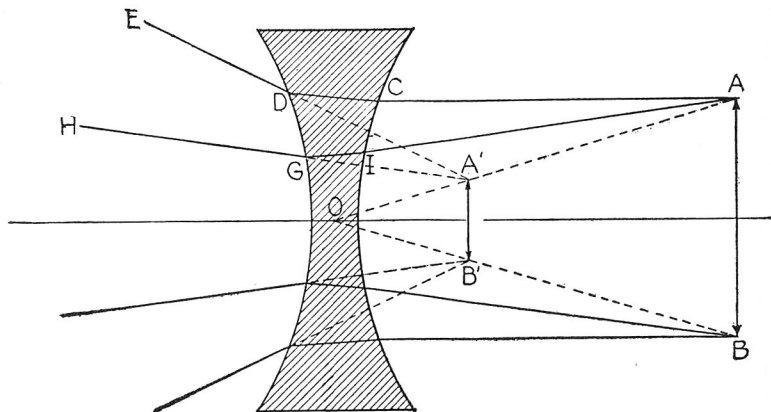


FIG. 7,776.—Formation of virtual image in double concave lens; no real image is formed with this type of lens. Let AB be an object placed in front of the lens. If the secondary axis AO be drawn from the point A , all rays AC , AI , etc., from this point are twice refracted in the same direction, diverging from the axis AO , so that the eye receiving the emergent rays DE and GH , supposes them to proceed from the point where their prolongations cut the secondary axis AO in the point A' . Similarly, drawing a secondary axis from the point B , the rays from this point form a pencil of divergent rays, the directions of which, prolonged, intersect in B' . Accordingly the eye sees at $A'B'$, a virtual image of AB , which is *always erect, and smaller than the object*.

of the foci of its several points. Accordingly images furnished by lenses are real or virtual in the same case as the foci, and their construction resolves itself into determining the position of a series of points.

Images are formed as follows:

1. The image formed with object *at twice the focal distance* is real, inverted, same size as the object, and at the same distance from the lens;
2. *At more than twice the focal distance*, the image is real, inverted, smaller than the object, and beyond the principal focus;
3. *At less than twice the focal distance*, the image is real, inverted; larger than the object, and more than twice the focal distance from the lens.

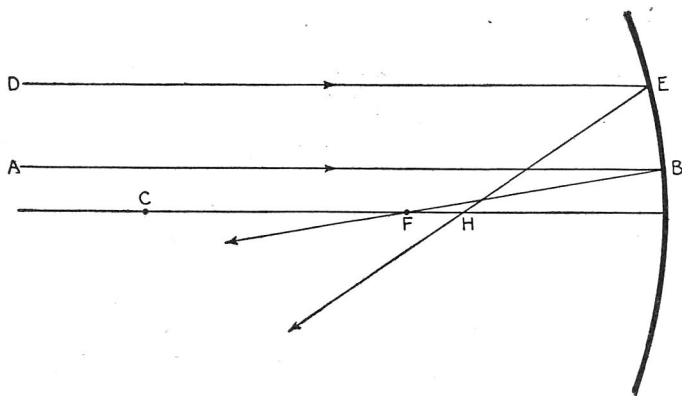


FIG. 7,777.—*Spherical aberration.* The reflected rays of concave spherical mirrors do not meet at exactly the same point. For instance, the ray AB, will be reflected to F, but DE will be reflected to H, a point closer to the mirror. This is called *spherical aberration*. It has been observed that the reflected rays only pass through a single point when the aperture of the mirror does not exceed 8 or 10 degrees.

4. When the object is at the principal focus, the rays after passing through the lens will be parallel, and no image will be formed.
5. When the object is between the principal focus and the lens the image is virtual, erect and larger than the object. In this case the rays are made less divergent but not convergent.

Formulae Relating to Lenses.—In all these lenses the relations between the distances of the image and object, principal

focus, also radii of curvature, the refractive index, etc., may be expressed by a formula.

If O be distance of the object from the lens, I the distance of the image, and F , the principal focal distance, then

$$\frac{1}{O} + \frac{1}{I} = \frac{1}{F} \dots \dots \dots (1)$$

From the equation it is seen that if any two of the distances are given the other can be found. Thus solving (1),

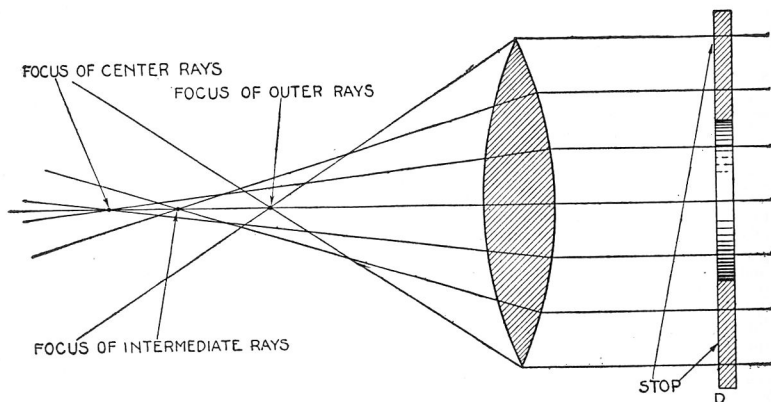


FIG. 7,778.—*Effect of spherical aberration. It produces a lack of sharpness and definition of an image.* If a ground glass screen be placed exactly in the focus of a lens, the image of an object will be sharply defined in the center but indistinct at the edges, and if sharp at the edges, it will be indistinct at the center. This effect is very objectionable, especially in photographic lenses. To avoid this, a disc D with a hole in the center is placed concentric with the principal axis of the lens, thus only the central part of the lens is used.

$$\frac{1}{I} = \frac{1}{F} - \frac{1}{O} \dots \dots \dots (2)$$

$$\frac{1}{O} = \frac{1}{F} - \frac{1}{I} \dots \dots \dots (3)$$

Chromatic Aberration.—When white light is passed through a spherical lens, *both refraction and dispersion occur.*

This causes a separation of the white light into its various colors and causes images to have colored edges. This defect which is most observable in condensing lenses is due to the unequal refrangibility of the simple colors, and is called chromatic aberration.

Achromatic Lenses.—The color effect caused by the chromatic aberration of a simple lens greatly impairs its usefulness. *This may be overcome by combining into one lens, a convex lens of crown glass and a concave lens of flint glass.*

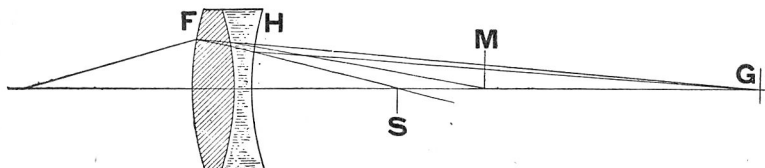


FIG. 7,779.—Achromatic lens, consisting of a combination of a double convex lens of crown glass, and a double concave lens of flint glass. Whenever it is desired to project especially good pictures upon a screen, lenses are often combined as shown in the figure. Here M indicates the line through the principal axis, at which the red rays reflected by the double convex lens would strike, and S, the line where the violet rays would be projected. The addition of the double concave lens brings the red and violet together again at G. A combination of two such lenses F H, placed the proper distance apart and the surfaces properly proportioned, may be made to combine any two of the colors of the spectrum. Accordingly even with these connected lenses there is always some coloring on the screen, although hardly noticeable.

The first lens produces both bending and dispersion; the second lens almost completely overcomes the dispersion without entirely overcoming the bending.

Principles of Optical Projection.—The process is almost the reverse of ordinary photography.

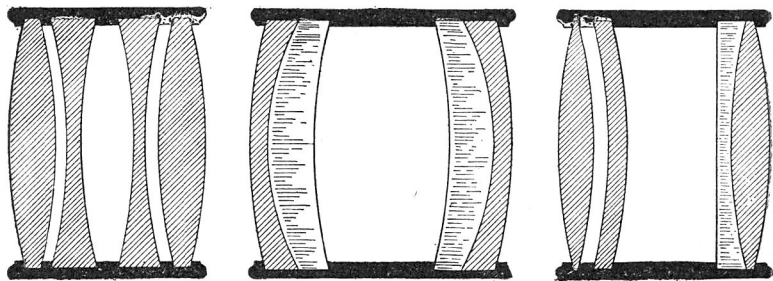
For instance, in photographing a scene by means of the photographic objective or lens, a reduced image is obtained on ground glass. This glass is replaced by a sensitized plate, and by the use of chemicals the image is fixed thereon.

In projection the process is reversed, that is, a transparent slide is made from the picture made with the lens, or the roll of film taken with a motion

picture camera is developed and used in the projection lantern or "motion picture machine" as it is usually called.

By means of a condensed light these are strongly illuminated, and with an objective lens, an enlarged image is projected upon the screen; this screen image corresponding to the real objects photographed.

The principles of optical projection for both lantern slide and motion picture apparatus will readily be understood from the diagram fig. 7,783.



FIGS. 7,780 to 7,782.—Various achromatic lenses. FIG. 7,780 and fig 7,781 are types usually used in photography, and fig. 7,782, a combination used in motion picture and stereopticon projection.

Rules

Size of Image.—**RULE:** *Multiply the difference between the distance from the lens to screen and the focal length of the objective, by the size of the slide and divide the product by the focal length.*

Example.—Let L be the projection distance, 40 feet or 480 inches; S , the slide mat 3 inches; F , the focus of the lens 12 inches. The formula for size of image, is

$$d = \frac{S (L - F)}{F}$$

where d = size of image substituting the given data

$$d = \frac{3 (480 - 12)}{12} = 117 \text{ ins. or } 9\frac{3}{4} \text{ ft.}$$

Focal Length.—**RULE:** *Multiply the size of the slide or film opening by the distance from the lens to screen, and divide the product by the sum of the size of the image and the size of the slide.*

Expressed as a formula

$$F = \frac{S \times L}{d + S}$$

substituting the values previously given

$$F = \frac{3 \times 480}{117 + 3} = \frac{1,440}{120} = 12 \text{ ins.}$$

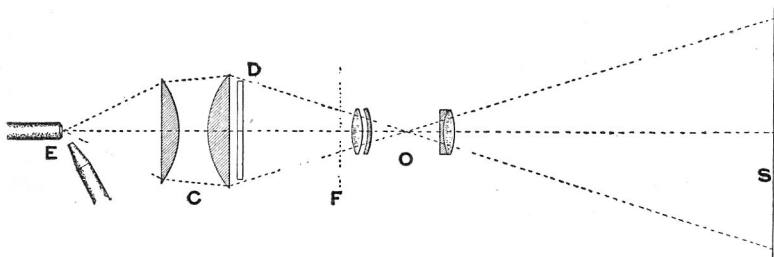


FIG. 7,783.—Diagram showing the various lenses of a motion picture machine and illustrating the principles of optical projection.

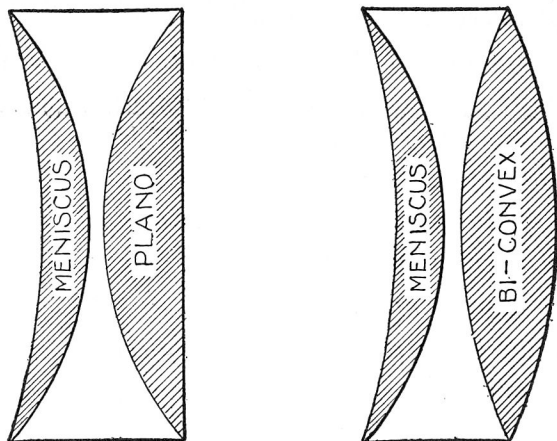
Distance from Slide to Screen.—**RULE:** *Multiply the sum of the size of the image and size of slide mat, by the focal length, and divide this product by the size of the slide mat.*

Expressed as a formula

$$L = \frac{F(d + S)}{S}$$

substituting the values previously given

$$L = \frac{12 (117 + 3)}{3} = 480 \text{ ins., or 40 ft.}$$



FIGS. 7,784 and 7,785.—Two forms of condenser. Owing to its form, the meniscus condenser will intercept and utilize a larger percentage of light rays from the arc than the plano, which means that more light will be transmitted to the film, when a meniscus condenser is used. The meniscus, however, because of being closer to the heat of the arc, is more liable to breakage. A combination consisting of one meniscus, and one bi-convex condenser is recommended.

TEST QUESTIONS

1. Define the term optics.
2. Explain the emission and undulatory theories.
3. Give definitions of the various terms used in optics.
4. Explain by diagrams the formation of images by plane mirrors.
5. What is the law governing angles of incidence and reflection?
6. What is a lens?
7. Give a classification of lenses.

8. *What is the focus of a lens?*
9. *Give explanation of foci in double convex lenses.*
10. *Explain with diagrams the formation of real and virtual images by double convex lens.*
11. *Explain spherical aberration.*
12. *Give the formulae relating to lenses.*
13. *What is chromatic aberration?*
14. *What is an achromatic lens?*
15. *State the principles of optical projection.*
16. *What is the rule for a, size of image; b, focal length; c, distance from slide to screen?*

CHAPTER 191

Motion Picture Cameras

Apparatus for taking motion pictures differs in many ways from ordinary cameras. Fig. 7,786 is a diagram showing the essential parts of a motion picture camera, from which the principles of operation are easily seen. As shown in the figure there are three compartments: 1, a front compartment U, containing a rotating shutter N, pin mechanism OP, and other parts not shown; 2, a compartment V, containing the film mechanism and magazines, and 3, a compartment on the opposite side containing mechanism communicating with the spools in the magazines, with the sprocket wheels, and the points in the first compartment.

The two magazines A,B, consisting of light boxes, fit into the back portion, and carry reels, W, X, on which the film is wound.

In operation, the roll of unexposed film L, which passes out of a small aperture H¹, at the corner of the top magazine A, around guide rollers C, D, engages by its perforations with the sprocket wheel F, to which it is kept by the roller E. The film forms a loop at H² and passes downward through the guide grooves made in the gate G.

Continuing, it passes out past the bottom of the gate, forming a second loop H³, and then passes between a spring roller I, and sprocket J, under the guide roller K, and enters at H⁴ the lower magazine B, when it is wound up on the bobbin X.

The sprocket wheels rotate continuously drawing the film from the supply at L, and taking it up at M.

The motion of the film in the gate G, however, is intermittent. During the period of rest, a surplus loop of film forms at H^2 , which is then pulled down through the gate by the action of the pin O, engaging with the perforations.

The whole mechanism is so arranged and geared together that, *while the film is being shifted, the light is excluded from the lens, and admitted during the stationary periods.*

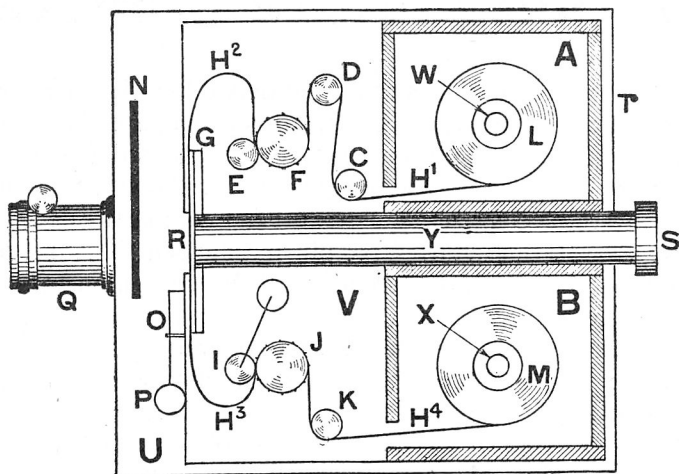


FIG. 7,786.—Diagram of motion picture camera showing the essential parts. Cameras are built for various numbers of pictures per turn of the crank; four, six, and eight are common. An eight picture camera should be run at a speed of almost one hundred turns per minute. To operate at this speed, get a watch ticking 300 ticks per minute and learn to count one, two, three; one, two, three, etc., just as fast as the watch ticks, turning the crank one revolution for every one, two, three counted; that is to say, one revolution per every three ticks of the watch

A long tube Y, extends through the center of the camera, and is provided with a detachable cap at S. This tube forms the sight hole for inspecting the image on the film, prior to exposure.

The gate G, is a kind of hinged door with an aperture in it, and its function is to keep the film flat and vertical during exposure and also to act as a channel or guide

After taking a subject, the operator presses a button, and in so doing punches a hole in the film at a point just above the gate, thus indicating the end of the subject and beginning of the next subject.

Camera Film Movement Mechanism.—The mechanism such as is used on the Bell and Howell camera is shown in fig. 7,787. It consists of two integral parts:

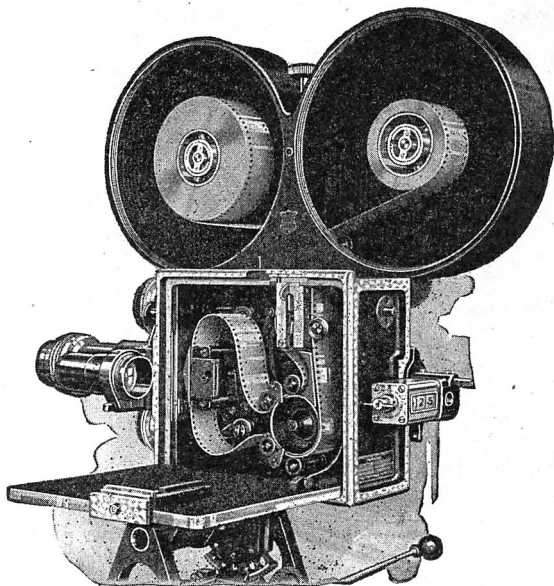


FIG. 7,787.—Bell & Howell motion picture camera; view showing camera and magazine interiors exposing film movement mechanism and threading of film.

1. Film feed and take-up sprocket;
2. Shuttle mechanism.

The film feed and take up sprocket is mounted directly to the main crank shaft by means of a lock nut and a hollow hexagon toothed washer.

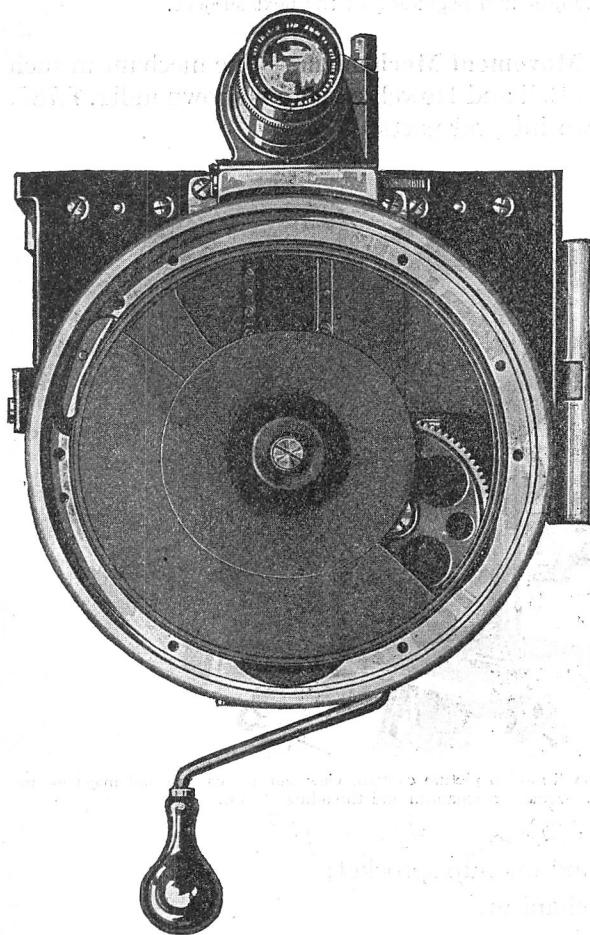


FIG. 7,788.—Bell & Howell camera. Front view with turret plate removed showing shutter, photographing aperture and part of brake mechanism.

This sprocket performs the double service of continuously drawing the unexposed film from the forward compartment of the magazine and delivering the exposed film to the rear compartment, where it is automatically rewound. Two sets of film guide rollers, upper and lower respectively, keep the film in proper engagement with the sprocket.

The shuttle mechanism comprises four distinct mechanical elements:

1. The shuttle bar carrying the engaging pins which impart the feeding motion to the film.
2. The register leaf forming the guideway for the film before the aperture.

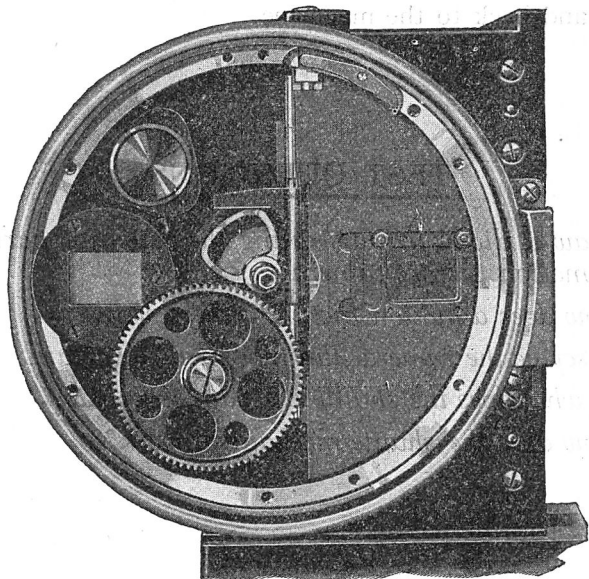


FIG. 7,789.—Bell & Howell camera. Front view with turret plate and shutter removed showing focusing and photographing apertures; shuttle operating cam, part of brake mechanism and opening for mounting focusing magnifier above focusing aperture.

3. The pilot register pins which cause the accurate register of the film before the exposing aperture. These pins are mounted above and in fixed relation to the aperture plate. Their specific function is to prevent inaccurate spacing, since an error in spacing to an infinitesimal degree causes unsteadiness on the screen in the projection of the picture.

4. The aperture plate against which the film is brought to register before the exposing aperture. This plate is mounted to the register leaf mounting

and is in fixed relation thereto. The opening in the aperture plate definitely establishes the marginal limits of the picture. Its rearward surface forms the seat against which the film is held in contact by the register leaf during exposure, thereby accurately locating the film at the focal plane.

The film movement mechanism thus described provides for the free travel of the film from the magazine through the camera and back to the magazine.

TEST QUESTIONS

1. *Draw a diagram illustrating the essential parts of a motion picture camera.*
2. *How does a motion picture camera work?*
3. *Describe the camera film movement in detail.*
4. *Of what does the shuttle mechanism consist?*
5. *How does the shuttle mechanism work?*

CHAPTER 192

Motion Picture Projectors

The function of a moving picture machine or *projector* is to *project motion pictures upon a screen*. The machine not only projects pictures on the screen, but is usually provided with apparatus for reproducing *synchronized sound*.

The projector proper consists essentially of:

1. An optical system, comprising

- a. Source of light;
- b. Lens { condenser;
objective.

2. Intermittent film feed-system, comprising

- | | |
|--------------------------------|--------------------------------|
| a. Upper reel; | g. Shutter; |
| b. Upper steady feed sprocket; | h. Lower steady feed sprocket; |
| c. Steady drum; | i. Lower reel; |
| d. Film gate; | j. Lower reel drive; |
| e. Intermittent sprocket; | k. Operating crank and drive; |
| f. Intermittent movement; | l. Numerous presser rollers. |

Besides these various essential parts, safety devices such as, fire shutter, fire valves, film shields, etc., are provided.

How a Projector Works.—The elementary diagram fig. 7,790 has been prepared to show in a very clear manner the operation of a projector. If the reader imagine the crank A, turned

counter clockwise he will have no difficulty in tracing the movements of the various parts.

The diagram does not represent any particular machine but is intended to give a clear idea of how the film is fed across the film gate intermittently and the synchronous operation of the shutter whereby the light is cut off from the screen during each movement of the film, with alternate "on" intervals while the film is at rest.

The operation of the projector is briefly as follows:

By turning crank A, in fig. 7,790, counter clockwise, the main shaft B, is driven through the 4 to 1 reduction chain drive D, a steady turning motion being caused by the fly wheel C, this in turn operates the upper steady feed sprocket E, through the 4 to 1 reduction gear F, thus the teeth of E sprocket which mesh with the perforations in the film, feed the film at a constant rate, the film being held against E by pressure roller G. A film loop or length of loose film is thus maintained between E and the steady drum H.

The film is fed past the film gate intermittently by the intermittent sprocket I, operated by the Geneva movement K, the latter producing a quick quarter turn of I, followed by a relatively long rest during which the main shaft B, makes one revolution.

The barrel shutter L, by a 2 to 1 gear with the main shaft and proper timing, operates to cut off the light rays from the screen during each movement of the intermittent sprocket I, and to admit the light during the intervals that I remains stationary. The synchronous operation of the intermittent sprocket and the shutter is very clearly shown in the diagram.

A lower steady feed sprocket M, which operates at the same speed as the upper sprocket E, maintains a lower feed film loop N, and feeds the film to the lower reel O. Because of the increasing diameter of the roll of film due to winding the film on reel O, the velocity of rotation of O must be allowed to vary; this is accomplished by means of the belt drive P, the belt permitting slippage below the maximum speed. *It should be carefully noted that the total revolutions made by each of the three sprockets E, I, and M, is the same, the only difference being that the motion of E and M is constant while that of I is intermittent.*

The object of the upper and lower feed loops is to lessen the inertia of the film by reducing the length of film subject to the sudden intermittent motion.

The film gate guides the film so as to prevent any lateral motion, flattens the film and by frictional resistance prevents the momentum of the film causing any up and down vibration.

The Intermittent Movement.—Various devices have been introduced for producing the intermittent movement necessary in projecting motion pictures. The movement consists essentially of an intermittent sprocket and intermittent gear.

The sprocket is a cylinder with teeth at each end, or for very light construction, it may consist of two hubs provided with teeth and properly

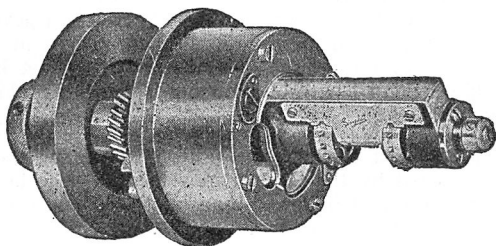
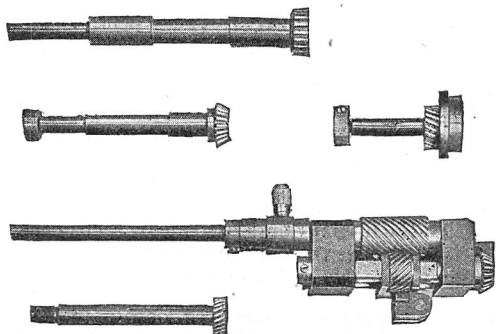


FIG. 7,791.—Simplex Geneva type intermittent movement.



FIGS. 7,792 to 7,796.—Simplex gears. The bevel and intermediate gears are made of formica, which material absorbs noise and damps the ring of metal gears.

spaced on a shaft to take the film. The teeth mesh with perforations in the film and thus secure a positive movement.

Of the various intermittent movements, the Geneva is extensively used and easily understood. Its operation is shown progressively in figs. 7,799 to 7,804.

The nature of the motion is as follows:

1. Begins slowly (fig. 7,800),

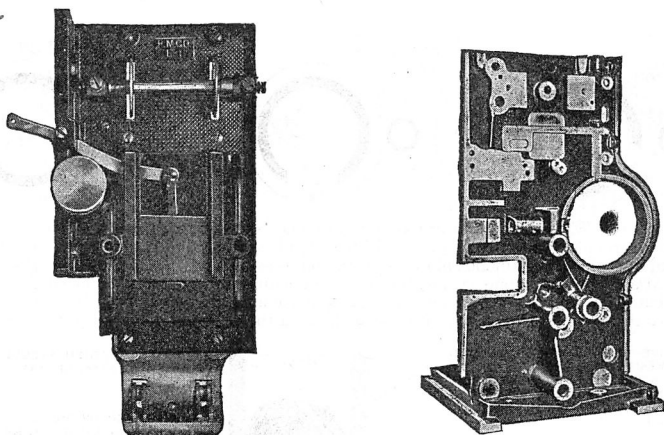


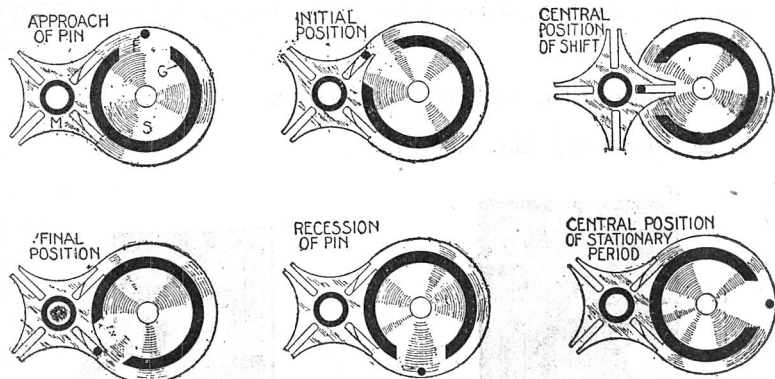
FIG. 7,797.—Simplex film trap. It has a felt runner type of tension shoe. The film guide may be removed from the mechanism by giving it a slight upward thrust; this permits ease and free access to all parts of the trap and door for the purpose of cleaning away emulsion, dust or dirt. Film trap is equipped with a slide in mask which eliminates the projection of the sound track to the screen. By slipping this mask in or out as desired, silent, sound on disc, or sound on film prints may be properly projected at will. A gate locking device also forms part of this assembly. This assures the projectionist that once the gate is closed it will remain locked in position during the projection of pictures. The gate may be released by a slight pressure of the finger when pressing on the opening device to which the lock is attached. The fire shutter is of the gravity type.

FIG. 7,798.—Simplex center frame.

2. Accelerates to a maximum at the mid position (fig. 7,801)
and

3. Gradually slows down to zero (fig. 7,802).

Light for Projectors.—Both arc and incandescent lamps are used to produce illumination for motion picture projection.



FIGS. 7,799 to 7,804.—Operation of Geneva movement shown progressively. *It consists of a maltese cross M, and a disc S, provided with a pin F, and circular guide G. In operation, the pin disc S, is in continuous motion and the pin is so located that it enters one slot of the cross M and carries it along with it, thus causing one-quarter revolution. The circular guide G, is cut away sufficiently to allow the cross to make a quarter revolution, but when it registers with the cross it holds the latter securely until the pin rotates around to the next slot.*

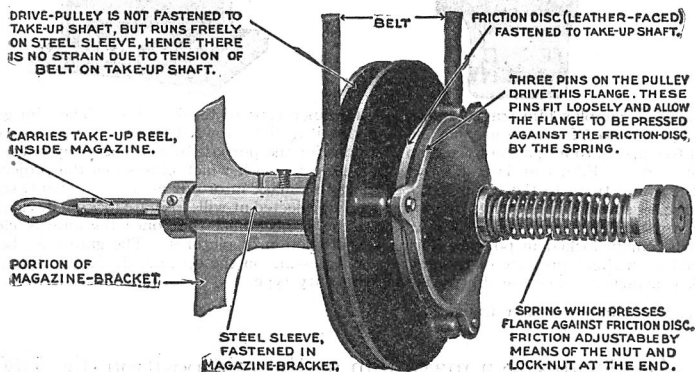
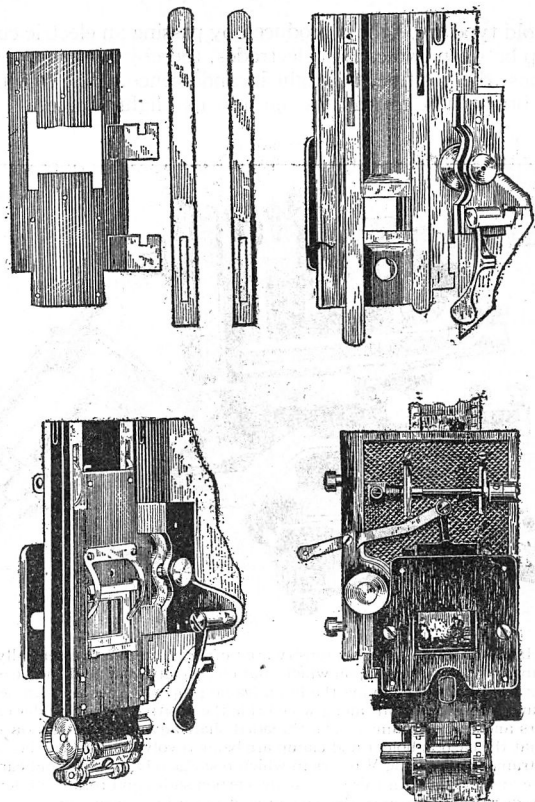


FIG. 7,805.—Simplex take-up device. *It is driven from the main driving gear, thus balancing the entire mechanism and equalizing the strain on the main driving shaft. The unit is adjustable for any desired tension. Two grooved pulleys are furnished permitting the use of reels with either 2 in. or 5 in. hubs.*



FIGS. 7,806 to 7,811.—Construction details of Simplex film gate. It is made of machine steel, the lugs securing the gate to the holder being electrically welded. Fig. 7,806 represents milled surfaces. The film trap shoes (figs. 7,806, 7,810), are of steel ground on both sides and beveled (fig. 7,806) to permit sliding into the dovetail slots (fig. 7,809). The lateral guide rollers (fig. 7,810 and 7,811) are of steel hardened and ground; the film cannot pass the guide rollers unless it be set between the two. If it should not be, it automatically rights itself. The distance between the rollers is adjustable by a set collar (fig. 7,811). The gate (fig. 7,810) is opened by threading by a light inward pressure on a thimble (fig. 7,811), and is closed by releasing the film trap door trip lever (fig. 7,810). Thus, in threading, there are only two operations: one to open, and one to close the gate. The intermittent sprocket tension shoe is made of ten pieces of hardened tool steel. The two inside shoes are offset and do not touch the film. The cooling plate (fig. 7,811) is made of two pieces of sheet steel separated $\frac{1}{4}$ inch, which arrests the heat by radiation and protects the fire shutter and aperture side of the film trap. The air space between the film trap is $\frac{1}{2}$ inch.

In the old type arc, light is produced by passing an electric current across an air gap between two carbon electrodes, thereby heating the tip of one of the carbons, the positive, to bright incandescence. The resulting, slightly concave, bright spot constitutes the principal light source.

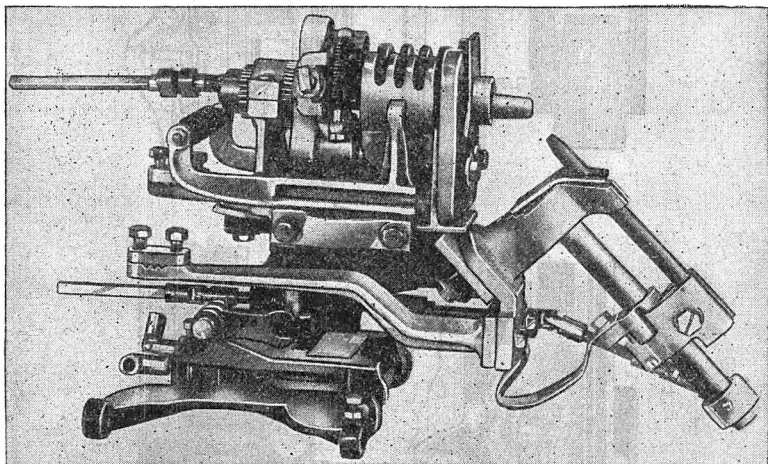
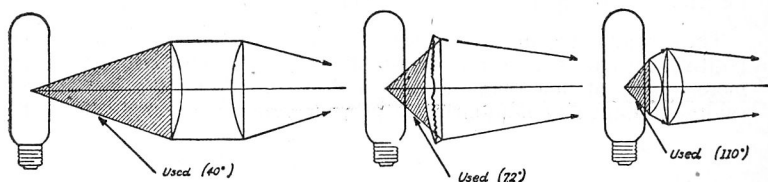


FIG. 7,812.—Hall and Connolly high intensity arc burner. *It consists* essentially of a combination tilting and swiveling stand upon which, but electrically insulated therefrom, is mounted an upright bracket casting carrying the lamp frame proper. The lamp frame carries a long spline shaft and a threaded shaft along which ride the positive carbon holder carriage with its rotating gears and carbon clamp. The threaded shaft advances the carbon carriage at the same time that the carbon holder and clamp are being revolved in the carriage. At the front of the lamp frame is a locating V recess in which rests loosely a half round carbon contact of ample surface and weight. In this contact the carbon slides and rotates under pressure from another contact resting on top of the carbon held down by a spring and lever. The carbon carriage is provided with a quick release from the worm drive for quick retrimming of the carbon. The length of travel of the carriage is sufficient to give 22 minutes of continuous burning at normal amperage. The positive carbon contacts are shaded from the heat of the arc flame by means of insulated, laminated shields made of heat resisting non-corrosive metal. The negative carbon unit consists of a pivoted self-aligning carbon clamp carriage sliding on two substantial rods or guides, the upper ends of which are rigidly attached to the guide head casting, which in turn is attached to, but properly insulated from, the same bracket casting carrying the positive unit. The guide head casting has a V recess into which the carbon is held and slides under tension of a tungsten spring located underneath the pivoted carbon holder carriage. The pivoted carbon holder and the V shaped guide head insure constant and correct alignment with the positive carbon and at the same time give to the copper coated negative a good wiping contact. Feeding motion is imparted to the negative carbon through a connecting rod coupled to a nut traveling on a long threaded shaft located on the back of the burner away from the direct heat of the arc.

In the high intensity arc, light is similarly produced by passing a heavy current across an air gap between two electrodes, but the position and composition of these electrodes are different.



FIGS. 7,813 to 7,815.—Comparison of arc and incandescent lights. The crater of the arc emits light only forward. With such a distribution the 10 in. or 12. focus plano condensers and a $1\frac{1}{2}$ in. diameter projection lens collect and utilize practically all of the light. The incandescent lamp emits light very nearly equally in all directions. Obviously, if the incandescent lamp be simply substituted for the arc, only a small portion of the total light emitted will be used as in fig. 7,813. Accordingly, in order to intercept more light, a much shorter focus condenser must be used. At first, a single piece corrugated condenser was used as in fig. 7,814 and later a triple lens aspheric condenser as in fig. 7,815. Such condensers pick up a solid angle of light of about 110° , as against 40° for the old plano condensers. In order to utilize the light which is given off to the rear of the lamp, a spherical mirror is placed behind the bulb, and so adjusted as to reflect an image of the filament coils back between the coils themselves. Thus instead of the 60° picked up in the arc system, we are utilizing the equivalent of 220° of solid angle. It is very important that the spherical mirror be accurately adjusted, in order to secure the best results.

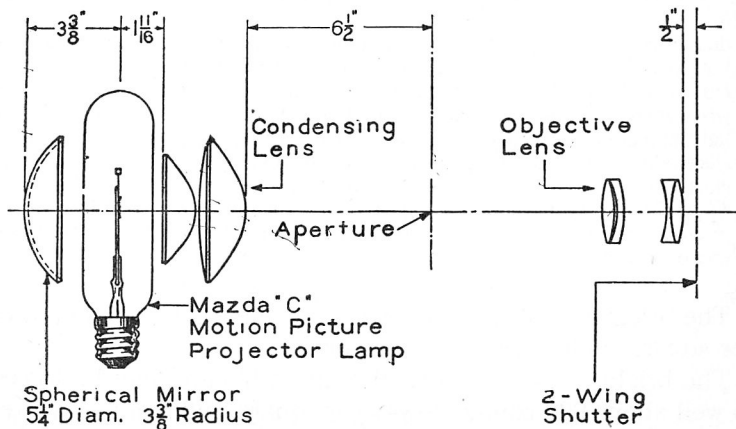
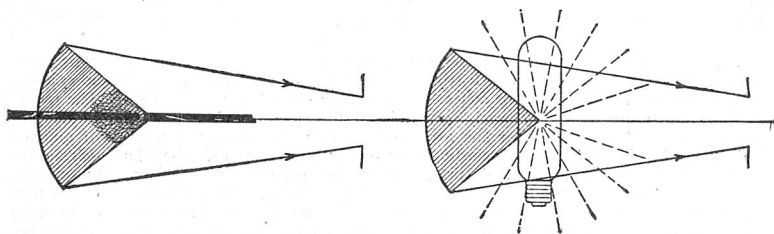


FIG. 7,816.—Optical train with incandescent lamp using Bausch & Lomb Cinephor condenser.

The *positive* is made up of rare earths, the principal one of which is cerium fluoride, and this rod of luminescent, arc sustaining material is encased in a thin shell of carbon. The negative consists of a copper coated heavy carbon shell surrounding a flame sustaining core. The *negative electrode* is positioned at an angle varying from 20 to 45 degrees according to the service for which the particular burner is intended

The current in passing across the air gap is concentrated in the core of the positive, causing great current density at this point. The core burns away more rapidly at first than the carbon shell, thus forming a cup shaped cavity more than $\frac{3}{8}$ of an inch in depth, tapering down from about $\frac{3}{4}$ the



FIGS. 7,817 and 7,818.—The standard arc lamp reflector, when used with an incandescent lamp, redirects but a small part of the available light through the condenser. Good results with incandescent lamp projection necessitate not only the proper equipment, but also very accurate adjustment of the various elements of the optical system.

diameter of the shell at the rim to about the diameter of the core at the bottom. In this cup or crater the luminescent gases from the core are generated and superheated, giving rise to tremendous temperature. *These gases are the light source* in the high intensity arc. This method of producing light is made possible by using sufficient current density, a special positive electrode of suitable structure and composition, by placing the negative electrode so that the arc stream is projected against the face of the crater to confine the positive gases, and revolving the positive carbon in order to prevent the rim of the crater burning away unevenly and letting the gases escape too rapidly.

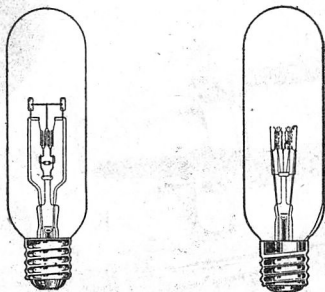
The brightness of the old type arc is about 140 candle power per square millimeter of crater surface.

The brightness of the new high intensity arc may be forced to well above 900 candle power per square millimeter of crater surface

Fig. 7,812 shows the gear and mounting of a high intensity arc lamp.

The construction and operation of a modern projector is shown in fig. 7,821.

Referring to illustration, the pedestal, carriage, adjustable support and base, constitute a single symmetrical unit. The stand rests on six leveling points and the projector is not attached to the floor or fastened to the building.



FIGS. 7,819 and 7,820.—Comparison of Mazda lamps. Fig. 7,819 shows a 28-32 volt, 900 watt, and fig. 7,820 a 1,000 watt Mazda projection lamp. The lower voltage lamp, on account of the shorter length of filament and its lesser liability to squirm when heated, has the desirable factor of greater filament concentration. **Reason for low voltage:** It is characteristic of tungsten filament that the higher the voltage, the smaller in diameter the wire must be, and the more it will squirm when it is heated and cooled. If 110 volt lamps were used the filament could not be concentrated into so small an area nor could it be run at quite so high a temperature. The greatest filament concentration possible, with the low voltage high current lamp is, therefore, the prime reason for its use. The useful size of light source is limited by the optics of the projector. The lens system will pick up light from a limited area and any light outside of this area is of no avail.

The underslung motor table O, is close to the base and the motor is accessible for oiling or regulating. It can be raised or lowered on its supporting rod by loosening two wing screws. The position of the motor on the stand is an important factor in eliminating vibration.

To tilt the projector, release locking handle A, attached to rear adjustable support, by turning it to the left, loosen pedestal adjustment locking nuts B and C, and pedestal adjustment hand wheel D, can then be turned with either hand to give desired angle. Micrometer adjustment can be made by means of the hand wheel, and compression springs E, on rear adjustable support make this extremely comfortable. When A, B, and C, are again locked, the projector is held rigidly in the proper position.

The lamp house can be placed in position for slides by loosening knobs F and G, firmly grasping slide over arm handle H, and drawing it to the left for the correct placing. Lamp house carriage K, turns on lamp house pivot

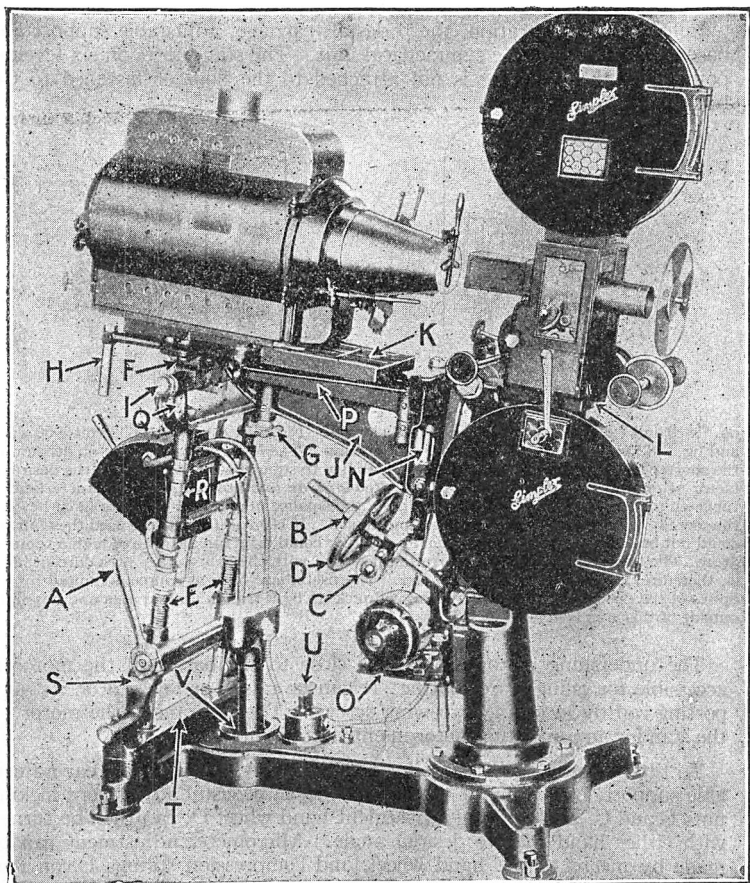


FIG. 7,821.—Model M, Simplex projector.

N, and at G, and slides over lamp house carriage rod I, and rear adjustable support. When F and G, are again locked, lamp house carriage K, is held rigidly in position.

The rear adjustable support consists of an upper fork Q, two rods R, and a lower fork S, swings on the pivot casting T. When the locking handle A, operates, it releases a powerful friction lock, and support rods R, are free to slip through the lower fork S. When the locking handle A, is released, the adjustable support ceases to act and hangs idle from the swinging table. When locked the rods and two forks constitute a structure that firmly connects the swinging table to the base. The 100 ampere switch and switch box are attached to the rear adjustable support. There is a foot motor switch U, for starting and stopping the projector and the 4 in. opening V, is provided in the base for installing a conduit.

TEST QUESTIONS

1. *What is the function of a motion picture machine or projector?*
2. *Of what does a motion picture projector consist?*
3. *Draw an elementary diagram illustrating how a projector works.*
4. *Describe the construction of the intermittent movement.*
5. *What is the nature of the motion due to the intermittent movement?*
6. *What is a take up device?*

7. Give construction details of the film gate.
8. How does a high intensity arc burner work?
9. Give comparison of arc and incandescent lights.

CHAPTER 193

Projector Operation

In the operation of projectors it should be noted especially that for continued perfect service cleaning and oiling are essential. The projection lens, the condensing lenses, and the mirror reflector should be thoroughly cleaned frequently. Oiling instructions should be carefully followed. The aperture plate and film gate collect a gummy substance especially from fresh film. This must be cleaned off to maintain the necessarily smooth surface for the film to ride upon.

Oiling.—Selecting the Super Simplex projector for illustration it will be noted in fig. 7,822 that all the bearings in the frame are reached by means of oil tubes A.

There is one bearing C, which has a direct oil hole on the side of the apparatus for lubricating the rear bearing of the shutter shaft. Do not overlook this hole in oiling.

The one oil tube which is not immediately visible is that which carries oil directly into the intermittent case and there is no wick in this particular tube. The method of oiling this is explained in fig. 7,822.

There are other minor oil holes which should receive oil occasionally, two which provide lubrication to the bearings of the film gate opening shaft, one which provides lubrication to the rear bearing of the frame shaft and two which provide lubrication to the bearing of the shutter adjusting shaft. The latter oil holes will be found under the framing lamp assembly. The only other oil hole on the mechanism is the one supplying oil to the outer bearing of the intermittent sprocket which is oiled through the ball oil cap D, fig.

7,823, in the same manner as in the old type Simplex mechanism with double bearing movement.

Of course, a small drop of oil should occasionally be placed on all slipping and sliding parts in order that they may work freely at all times and also on the gear teeth so that the mechanism may operate smoothly.

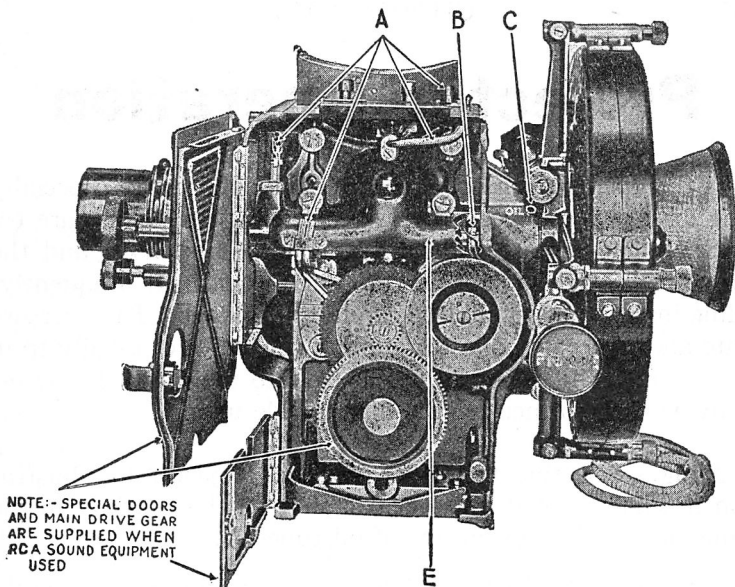


FIG. 7,822.—*Super-Simplex oiling system.* Oil intermittent casing as follows: Set the framing handle to the position which brings the red line on the oil sight to a horizontal position; in the shutter shaft support casting E, just above the fly wheel of the intermittent movement, will be found a window or hole milled through the casting through which can be seen a portion of the shutter shaft. Just in front of the shutter shaft is the oil tube B, leading to the intermittent casing. This oil tube can be reached in one position only; this position is obtained by moving the framing handle as before directed. Enough oil should be inserted through this tube to bring the level in the oil case up to the red sight line, and no more, when machine is level; use judgment when projector is not level.

Sound Aperture and Picture Centering Device.—The Super Simplex projector is supplied with the vertical sliding aperture plate in which are two standard apertures, one having the

standard dimensions for straight silent film projection, $.906 \times .6795$, and the other having standard dimensions for sound film projection $.800 \times .6795$, or the proportional aperture, $.800 \times .607$ for the projection of sound film to give a screen picture

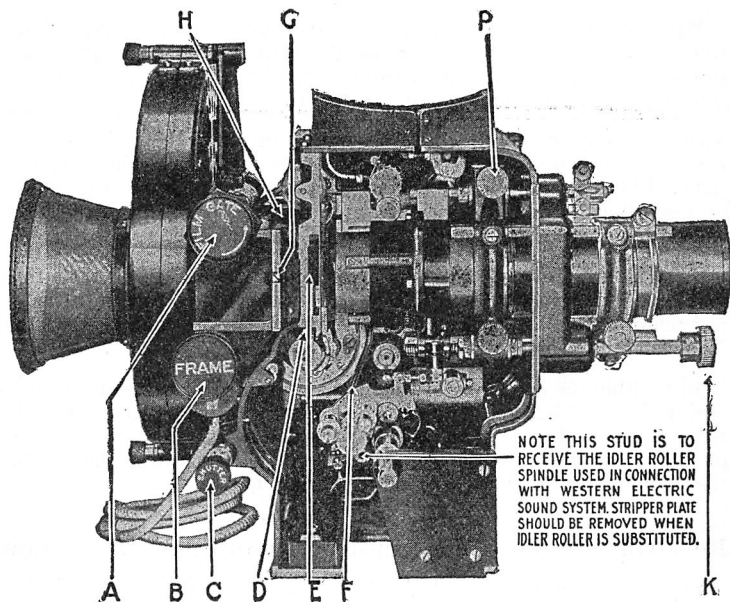


FIG. 7,823.—Super-Simplex projector; view showing aperture plate, outer bearing of intermittent sprocket, etc.

of the same dimensions as obtained with the standard silent projection aperture.

With the use of this latter aperture it is necessary to change to shorter focal length lenses and this can be done in the Super Simplex as is explained under Method of Mounting Lenses.

Aperture Plate.—This plate E, fig. 7,823, slides vertically behind the film tracks on the film trap. In its upper position

it carries the standard silent film aperture. When slipped into the lower position it carries the standard sound film aperture or the standard proportional aperture, depending on which was ordered with the projector.

When using the standard sound film aperture or the proportional aperture it is obvious that the lens mount with relation to the center of the aperture is off center, due to the masking of the sound track, and, therefore, throws the picture to one side on the screen.

On the front and top of the lens mount, outside of the mechanism, fig. 7,824, will be found a lever A, which may be thrown laterally from left to right. In the position shown the lens is accurately centered on the standard or proportional sound film aperture, and thrown over to the left position it will be centered for the standard silent or disc aperture.

Stops B, are provided on this adjustment so that the length of its throw may be pre-determined in order that the lens may also come into the correct relation with the projection apertures and the projected picture; these stops fetch up against the stationary stop shaft C.

Just within the glass door of the mechanism in the upper right hand corner, see P, figs. 7,823 and 7,826, will be found a lens holder lock screw. This screw is attached to a clamp provided in order that the lens centering lever may, if desired, be locked in fixed position and also to apply a slight tension that eliminates vibration of the lens centering unit.

Revolving Shutter.—The construction of this detail is shown in fig. 7,825. The method of setting the shutter is explained in the illustration.

Eye Shield.—This device, which protects the projectionist's eyes from the bright rays from the spot at the aperture, is enclosed and the colored glass therein may be removed for cleaning by loosening screw G, in fig. 7,823.

This eye shield together with the framing and threading lamp are attached by means of screws to the front section of the shutter guard. A slot H, fig. 7,823, is provided in the eye shield assembly just behind the aperture, so that change over devices using an aperture cut off may be readily adapted.

Threading and Framing Lamp.—This lamp shown at D, fig. 7,824, directs a strong beam of light up behind the eye shield to the aperture and by this means it is possible for the projectionist to place the film in frame readily while threading the projector.

A small switch F, is provided by means of which the lamp may be thrown on or off at will. The framing lamp assembly is connected by armored cable to any convenient source of 110 volt supply.

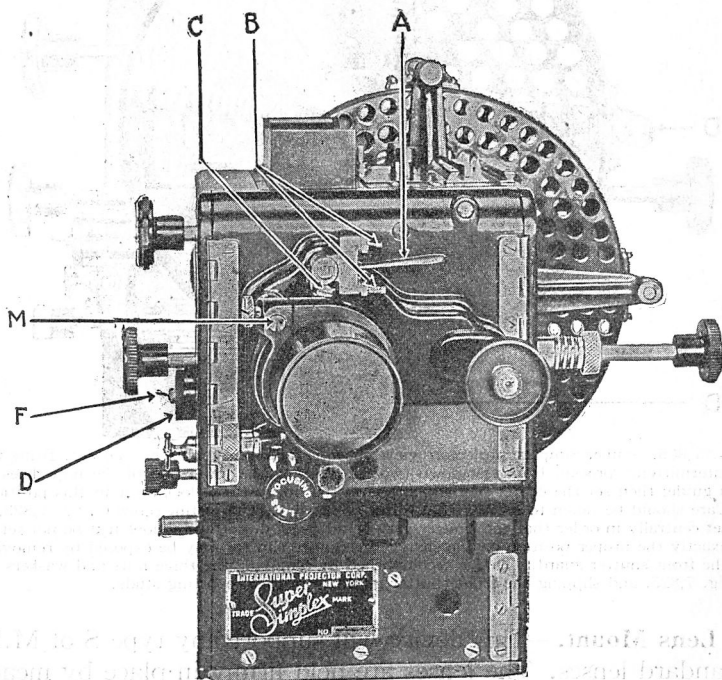


FIG. 7,824.—Super-Simplex projector; view showing adjusting lever, threading and framing lamp, etc. **To replace lamp:** Loosen screws which hold switch assembly and lamp socket in lacquered barrel; the entire assembly may then be removed and lamp readily replaced.

Gate Opening, Framing and Shutter Adjusting Knobs.—These knobs are plainly visible on the projector and very little need be said with regard to their operation. These knobs are shown in figs. 7,823 and 7,826 and explained in fig. 7,826.

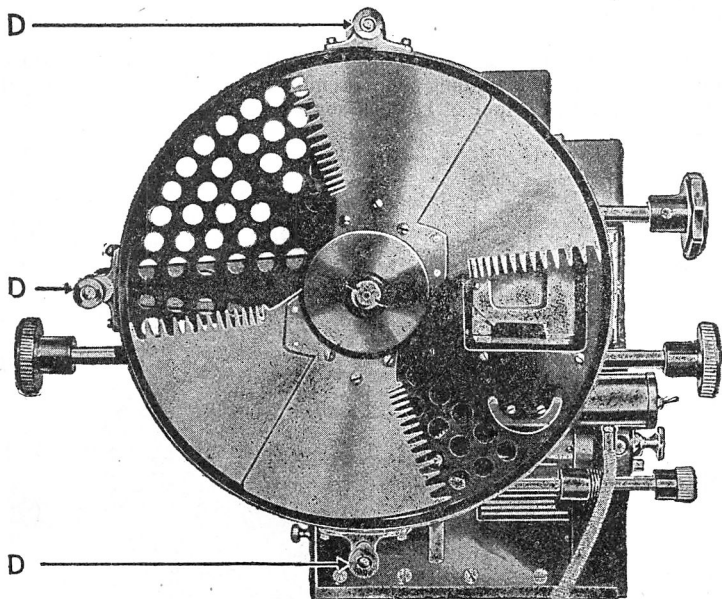


FIG. 7,825.—Super-Simplex projector; view showing revolving shutter. *To set:* Bring the intermittent sprocket from rest down two teeth, using the lower end of the film shoes as a guide; then set the center of the shutter on the optical axis, locking it in this position. Care should be taken to see that the throw of the shutter adjusting screw C, fig. 7,823, is set centrally in order that the shutter may be adjusted in both directions if it be not set at exactly the proper position on the shaft. The entire shutter may be exposed by removing the front shutter guard. This is accomplished by removing the three nuts and washers D, fig. 7,825, and slipping the front shutter guard from its supporting studs.

Lens Mount.—This device will support any type S of M.P. standard lenses. The lenses are held firmly in place by means of two lens clamps, one within the projector mechanism G, fig. 7,826, and one H, on the outside on front of the mechanism.

Half size Ross lenses may be accommodated but it will be found that in many focal lengths the large barrel diameter K, fig. 7,827, is several thousandths of an inch below the American standard, and where this discrepancy

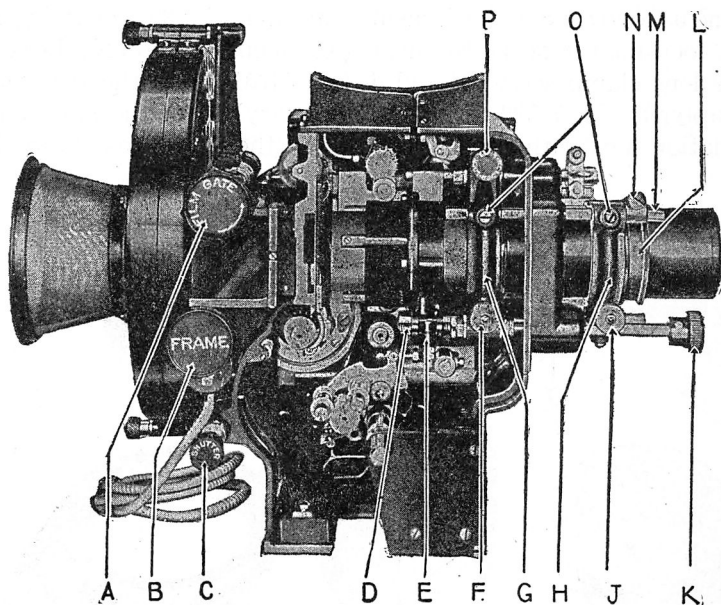
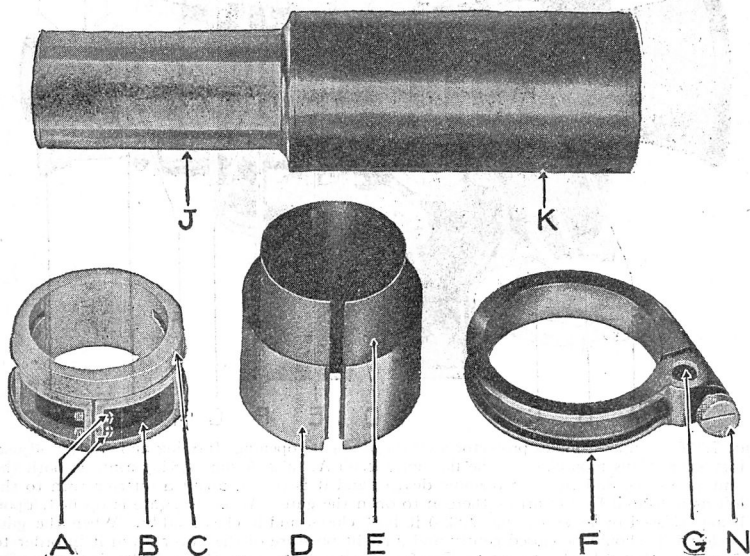


FIG. 7,826.—Super-Simplex projector view showing gate opening, framing and shutter adjusting, knobs, lens mount, etc. The film gate knob A, (also A, fig. 7,823) controls both the film gate latch and the gate opening device, and it is turned about a quarter turn to the left as indicated by the arrow thereon to open the gate. When the gate is opened, upon being released by lever F, (fig. 7,823) it both closes and latches readily. When the gate is closed, it should be closed gently and a slight pressure of the finger given it in order to make sure that it latches properly. The framing handle B, (also B, fig. 7,823) is so mounted upon the shaft that when the word *frame* is read in a horizontal position, as indicated, the framing device is centrally located, allowing approximately the same throw to right and left for framing purposes. The shutter adjusting knob C, (also C, fig. 7,823) is connected through the gear train and shafts to the shutter shaft and turning it in either direction will revolve the shutter shaft to the right or left respectively, so that the shutter may be accurately set with the projector in operation after it has been temporarily set and locked on the shutter side. Care should be taken to see that an equal amount of throw is allowed in the shutter adjusting mechanism when the shutter is locked upon the shaft. The lens focusing knob K, (also K, fig. 7,823) projects out through the front of the mechanism and is of the micrometer type. One complete turn of this knob moves the lens mount forward or backward approximately .040 ins., depending upon the direction of its rotation.

is discovered it will be necessary sometimes to use shims similar to that shown at D, fig. 7,829, in the front clamp H, fig. 7,826.

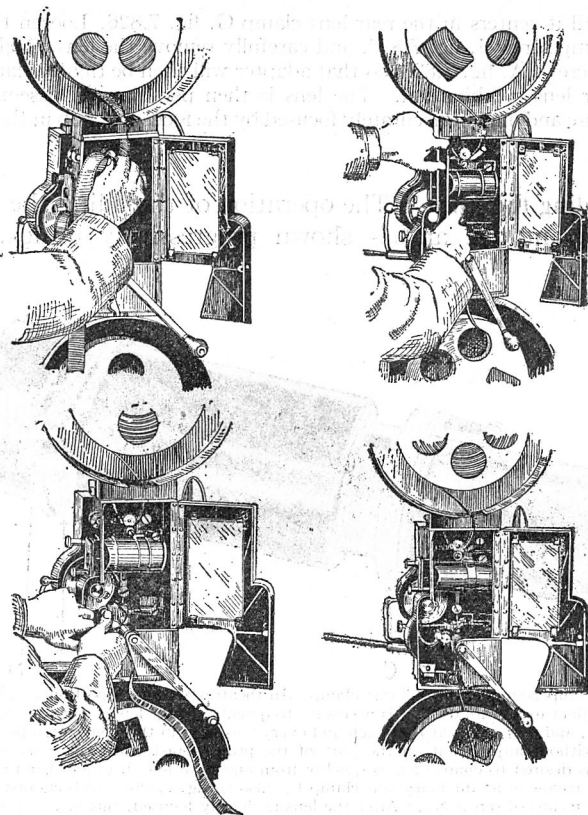
Method of Mounting Lenses.—This operation should be done as follows: Set the focusing nut E, fig. 7,826, centrally on the focusing thread D, by turning the focusing knob K. Loosen the lens clamp screws F and J, fig. 7,826. Slip the rear lens adapter B, fig. 7,828 (if one be necessary), over the rear combination lens without clamping it on the barrel, as shown in



FIGS. 7,827 to 7,830.—Super-Simplex lens adapter parts.

fig. 7,835. Slip the lens in through the front of the lens mount and bring it into approximate focus by sliding it back and forth in the mount.

When in focus, slightly tighten the front lens clamp screw J, fig. 7,826, so that the lens will not slip. Slip the rear lens adapter B, fig. 7,835, along the



FIGS. 7,831 to 7,834.—“Threading” a typical motion picture machine. Fig. 7,831 illustrates the method of threading the film through the film trap by forming the upper loop with the second finger of the left hand and gripping the film below the intermittent sprocket with the first finger. Fig. 7,832 illustrates how the film is threaded through the film trap by forming the upper loop with the second finger of the left hand and gripping the film below the intermittent sprocket with the first and third fingers of the right hand and closing the film trap gate by tripping the film trip lever with second finger. Fig. 7,833 illustrates the method of forming the lower loop, threading the film over the lower feed sprocket and closing the lower feed sprocket roll arm by a downward pressure with the first finger of the right hand. The film is then inserted through the fire valve by means of the slot in the base of the mechanism and is then fastened on to the lower reel so as to rewind to the right. Fig. 7,834 shows the machine completely threaded from the top reel to the feed sprocket through the film trap and on to the lower feed sprocket and the take up reel.

lens until it centers in the rear lens clamp G, fig. 7,826. Loosen the front lens clamp screw J, fig. 7,826, and carefully remove the lens. Tighten the clamp screws A, fig. 7,828, so that adapter will then be tightly clamped on the rear lens combination. The lens is then permanently assembled for future use and may be accurately focused by the focusing knob in the regular way.

Threading the Film.—The operation of threading the film is an important one and is shown progressively in figs. 7,831 to 7,834.

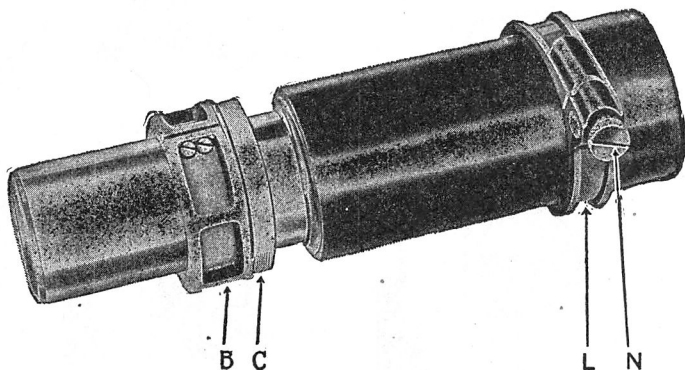
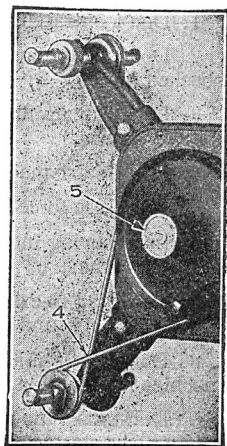
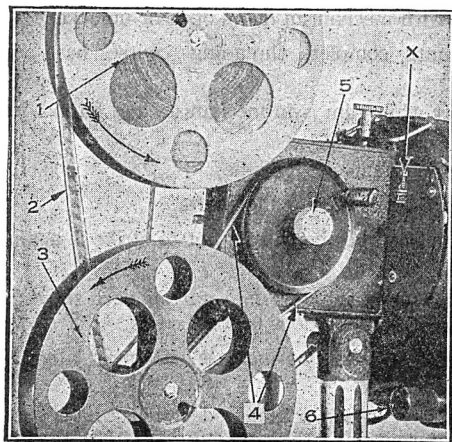


FIG. 7,835.—Super-Simplex fixed focus clamp. In theatres where proportional size aperture plates or effect masks are used, it is necessary to quickly change lenses from one focal length to another, and it is essential that each and every lens used in this connection be absolutely in focus without adjustment on the part of the projectionist when the change is made. Where it is desired to change lenses quickly from one focal length to another this is taken care of by means of an auxiliary lens clamp L, (also L, fig. 7,826) which clamps to the lens proper by means of screw N. After the lens is sharply focused, this auxiliary lens clamp is slipped over the front end of the lens barrel and brought tightly against the front lens clamp as shown at L, in fig. 7,826.

Starting the Projector.—After the projector has been properly oiled, film properly threaded, framed and adjustments made, the following directions (which relate especially to the Superior projector) should be observed:

1. Strike arc by adjusting carbon holders and throwing knife switch.

2. Especially on new equipment the star and cam should be eased off before starting. Instead of accomplishing this by turning the fly wheel as formerly, it is now done by an adjusting knob located at the front end of the direct motor drive shaft. A slight turn of this knob will serve to ease off the star and cam and thus allow easy starting, and also save much wear on these vital parts.



FIGS. 7,836 and 7,837.—Rewinding film on Victor Cine projector. **Instructions:** Place the full reel 1 on the left shaft of the upper reel arm so that the film 2 comes off the reel from the front and is attached to hub of empty reel 3 as shown. When rewinding by hand loosen clutch knob 5 by turning to right. If rewinding by motor, rewind belt 4 must be crossed as in fig. 7,837 and clutch 5 tightened by turning firmly to right. A film may be rewound while another is showing. This is a great convenience when the same film is to be shown more than once during any one exhibition. When rewinding by motor it is not necessary that the lamp remain lighted. Remove plug 6 to disconnect lamp current. Incorrect rewinding on the Victor Cine projector is impossible because of an automatic clutch in the take up shaft which prevents revolving of the spool in incorrect direction. If a new film before projection has been wound on the reel incorrectly, inside out, it must be rewound twice, so that the starting end is on the outside.

3. Engage motor by pulling or pushing the motor switch located at the rear of the cradle and under the lamp house. This can be done from either side.

4. Variation in speed is accomplished by turning speed knobs, located on either side to the left or right as occasion requires. Changing speed should be done slowly rather than abruptly.

5. Crank handle should always be close at hand in case of an emergency. Should any trouble develop with transmission continue running of projector by means of hand crank, immediately disengaging the motor.

Operating Hints.—The following suggestions in the form of “don’ts” will be found of value to the projectionist:

1. Don’t operate machine with mechanism doors open or unlocked.
2. Don’t start machine until complete threading course has been checked up.
3. Don’t lift up fire shutter while film is in mechanism and lamp house dower is open.
4. Don’t start machine until picture is in frame.
5. Don’t use force in driving pins or removing shafts.
6. In removing intermittent sprocket be careful not to strike it against sides of machine.
7. Don’t fail to examine and test machine before starting each show. It will save trouble and is required by regulations in some cities.
8. Don’t start machine with a jerk, but increase the speed after the machine is in motion.
9. Don’t have too much tension on pad or film guide. This causes undue wear on the star wheel and intermittent sprocket, and may injure the film.
10. Don’t let film trap slam after threading, as the film may be thrown off sprocket and ruined when machine starts. Place finger against film trap and let it close easily.
11. Don’t use steel to scrape the emulsion off the film trap and tension springs. Use edges of a coin or piece of copper or other soft metal.
12. Don’t force the machine when it seems stiff. It may need oil or an obstruction may have found its way into the working parts.
13. Don’t forget to re-time or set the shutter after removing the intermittent case from the machine.
14. Don’t use graphite in any part of the mechanism. It will not only ruin the gears, but will eventually destroy the bearings and entire mechanism.
15. Don’t use alcohol, benzine, kerosene or turpentine as a lubricant. Either Simplex oil or oil of a similar quality is the only machine lubricant recommended.

16. Don't use oils "that clean as well as lubricate." Any oil that is powerful enough to eat rust will also eat any of the bearings and shafts.
17. Don't fail to give mechanism a kerosene bath at least once a month.
18. Don't try to put enough oil into mechanism at one oiling to last a week, but use less oil and use it oftener.
19. Don't forget any of the oil holes. They are there for a purpose and every one of them is important. Locate each one of them on the instruction plates.
20. Don't fail to oil machine every time before using, particularly the intermittent movement—"the heart of the mechanism."
21. Don't put vaseline, grease or packing of any kind into the intermittent casing.
22. Don't allow oil to touch friction discs of speed control, if of fibre type.
23. Don't fail to keep leather friction disc well oiled.
24. Don't use oil on the arc lamp, as it quickly burns off and causes lamp to bind. For the arc lamp, use graphite for lubrication.
25. Don't fail to keep lenses and condensers clean at all times.
26. Don't use a rough cloth or waste to clean these optical units. A piece of chamois, linen or soft cloth moistened with ammonia will give the best results, and remove all dirt as well as giving a high polish. Use equal parts of ammonia and water.
27. Don't fail to examine all electrical connections on lamp, rheostat or motor. For any electrical device to be efficient all connections must be firmly tightened.
28. Don't allow water or any dampness to penetrate the rheostat or motor.
29. Don't fail to keep the commutator and brushes on the motor perfectly clean.
30. Don't allow the brushes to wear down too low or commutator will become pitted and the motor will lose speed and be ruined.
31. Don't hold the idler pulley too slow up on titles, as this imposes a strain on the motor. Use the speed control.
32. Don't fail to oil the armature shaft frequently.
33. Don't neglect the arc lamp connections. High amperage eventually chars the asbestos lead nearest the lamp and efficiency requires that a new connection be made every week.

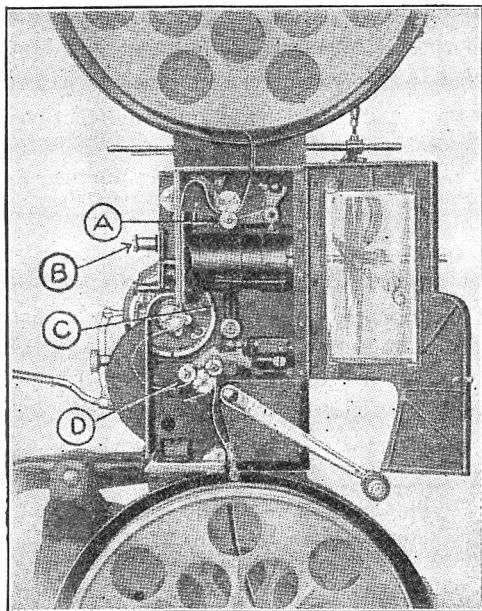


FIG. 7,838.—Threading the Simplex projector. First see that a loose length of approximately five feet of film is left hanging from the loaded reel, which reel is placed into the upper magazine in such a position that the film will feed into the mechanism from the top of the reel, and with the dull or emulsion side of the film facing the lamphouse. The five foot length of film is necessary to provide sufficient length for threading, forming of loops, and still leave enough to make several turns around the lower empty reel to insure its security. Now feed the edge of the film into the slotted section of the magazine roller valve, and fasten the door of the magazine. Then open up guide rollers A and D as well as the film gate. The film gate is opened by pushing against plunger B until gate is fully opened, when it automatically locks itself into open position. Now pass the upper section of loose film under the upper feed sprocket, making sure that sprocket teeth engage accurately with film sprocket holes. This is ascertained by passing finger lightly over engaged teeth, and making sure that teeth protrude through sprocket holes. Then close roller A and pass remainder of film over top of gate and see that both edges of film are squarely between the two circular film guides. Now with the index finger of left hand raise the loose film so that a loop as here shown will be formed. Then, making sure that film is squarely located upon film tracks, bring the film around under side of intermittent sprocket, and while holding index finger of left hand in the upper loop, maintaining a slight upward pressure against the loop, trip the catch marked C with the index finger of the right hand, which operation will close and lock the gate in operating position.

NOTE.—**Warning.**—When catch C in fig. 7,838 is released there is a tendency for the gate, released of its confinement, to shoot suddenly toward film, so it is advisable to retard this sudden momentum by a slight pressure of the hand against it.

34. Don't use oil or grease on lamp joints or rods. Use a little powdered graphite at the joints.

35. Don't allow carbon dust or other dirt to accumulate in the lamp-house. A small pair of hand bellows will blow out all dust.

36. Don't have any loose contacts or burnt asbestos leads on the lamp. Burnt or broken leads mean trouble while machine is in use.

37. Don't try to get good results with poor carbons.

38. Don't try to get good results with dirty or pitted carbon jaws.

39. Don't remove pins from intermittent sprocket without proper support for sprocket.

40. Don't attempt delicate intermittent repairs without proper tools.

41. Don't adjust take up tension spring too tightly. Too much tension wears sprockets and damages film.

42. Don't run machine with magazine doors open.

43. Don't allow cold air draught from fan or other sources to blow into lamp house. Such draught will invariably result in condenser breakage.

44. Don't put foreign or home made attachments of any kind upon machine without consulting the builders.

45. Don't screw up condenser rings and holders too much.

46. Don't fail to wash sprocket teeth at least twice a week with stiff bristled tooth brush dipped in kerosene.

47. Don't fail to keep aperture plate clean.

48. Don't fail to keep film loops as small as possible. Large loops are noisy and unnecessary.

49. Don't fail to close lamp house dowsers if film breaks.

50. Don't fail to match "O" marks when replacing gears.

NOTE.—After making sure that the film is safely confined between the sides of the intermittent guides, form the lower loop as in fig. 7,838 and place film over the lower sprocket teeth, making sure of its engagement with the teeth; then close down roller D and feed film edgewise into lower magazine slot. A sufficient length of film is left, the end of which is fastened into reel clip of the empty reel in the lower magazine and the slack between the reel and the lower sprocket is taken up by making several turns with the empty reel, thus tightening up the film, which is now ready for action.

NOTE.—Before running machine it is necessary that all doors of the mechanism be closed and locked, as the Simplex is so designed that the film is best safeguarded against fire or damage when the mechanism is entirely enclosed.

51. Don't fail to remove oil box complete when adjusting intermittent sprocket.

52. Don't fail to keep pad rollers adjusted to one thickness of film.

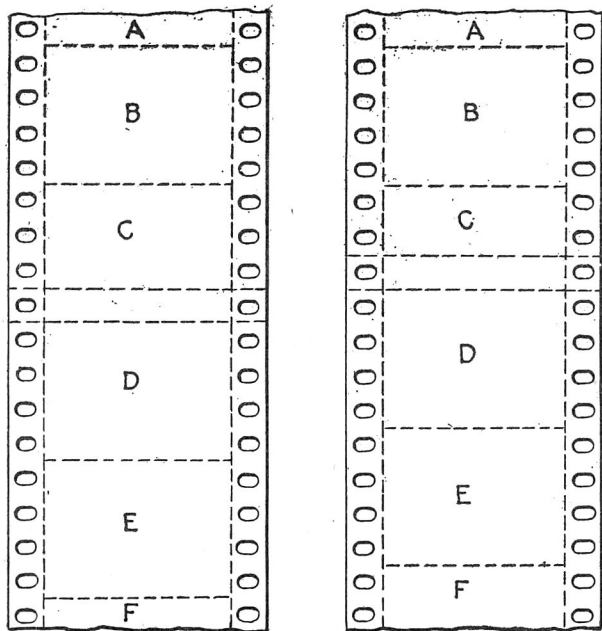


FIG. 7,839.—Splice in frame. The picture C has four holes at the side, just as have the pictures A, B, D, E, etc., and when that film is passed through the film gate and intermittent mechanism, the framing will be preserved, because mechanically the film is the same in distribution of pictures and of sprocket holes as though no splice had been made. The difference is found in the "jump" of the pictures when one or more pictures have been omitted, but the "frame" will not be disturbed as the splice passes.

FIG. 7,840.—Splice out of frame. The picture C has but three holes at the side. Hence, when the picture B is pulled out of the film window and C is pulled in, the intermittent sprocket pulling down four holes will pull into the film window the three-quarter picture C, and also the top quarter of the whole picture D. At the next shift, the intermittent sprocket pulls down another four holes, pulling into the film window the remaining three-quarters of D, and the top quarter of E, etc. This continues until the operator notices the screen and frames with his lever. This is called a splice "out of frame" because the splice throws the picture out of frame in passing.

53. Don't bend the intermittent guide apron. To do so may result in serious film damage.

54. Don't forget to oil the take up spindle.

55. Don't fail to oil the pad rollers.

56. Don't fail to see that all pad rollers are turning when machine is in action.

How to Splice Film.—Cut one end on the line between pictures and cut the other end with a quarter picture on; thus in cutting a film there will be three quarters of a picture cut out, a picture and three quarters, etc. Moisten the gelatine on the quarter picture and scrape it clean, also scrape the celluloid side of the other end clean. Spread cement on the cleaned quarter picture space and fit it on the back of the other end, sticking the two ends together with the picture lines matching and the sprocket holes matching. Cut either through a sprocket hole or midway between sprocket holes straight across the film.

TEST QUESTIONS

1. *What are the two principal requirements for maintaining a projector in perfect condition?*
2. *Give full directions for oiling.*
3. *Describe the picture centering device.*
4. *How does the aperture plate work?*
5. *Explain method of setting revolving shutter.*
6. *How is the eye shield arranged?*
7. *What is the object of the threading and framing lamp?*
8. *Explain the manipulation of the gate opening, framing and shutter adjusting knobs.*

9. *How are lenses mounted?*
10. *Describe in detail the operation of threading a typical motion picture machine.*
11. *Describe how the projector is started.*
12. *Describe the operation of rewinding the film.*
13. *Give 56 operating hints.*
14. *Explain in detail how to splice film.*

CHAPTER 194

Physics of Sound

Production of Sound.—When air is set in vibration by any means, sound is produced provided that the frequency of vibration is such that it is audible. If a violin string in tension be plucked, as in fig. 7,841, it springs back into position, but due



FIG. 7,841.—Sound produced by vibration of violin string.

to its weight and speed, it goes beyond its normal position, oscillates back and forth through its normal position, and gradually comes to rest. These vibrations produce sound.

As the string moves forward it pushes air before it and compresses it, also air rushes in to fill the space left behind the moving string. In this way the air is set into vibration. Since air is an elastic medium, the disturbed portion transmits its motion to the surrounding air so that the disturbance is propagated in all directions from the source of disturbance.

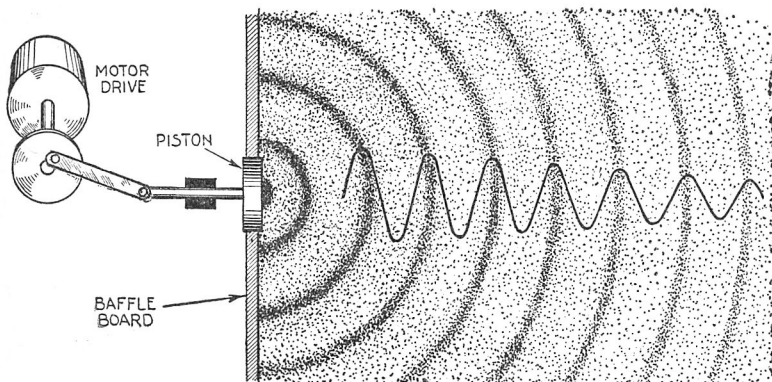


FIG. 7,842.—Generation of sound waves by the rapid oscillation of a light piston. *As the piston oscillates* the air in front of the piston is compressed when it is driven forward, and the surrounding air expands to fill up the space left by the retreating piston when it is drawn back. Thus a series of compressions and rarefactions (expansion) of the air is the result as the piston is driven back and forth. Due to the elasticity of air, these areas of compression and rarefaction do not remain stationary but move outward in all directions, as shown.

If the string be connected in some way to a diaphragm such as the stretched drum head of a banjo, the motion is transmitted to the drum. The drum, having a large area exposed to the air, sets a greater volume of air in motion and a much louder sound is produced.

If a light piston several inches in diameter, surrounded by a suitable baffle board several feet across, be set in rapid oscillating motion (vibration), as in fig. 7,842, by some external means, sound is produced.

Propagation of Sound.—If the atmospheric pressure could be measured at many points along a line in the direction in which the sound is moving, it would be found that the pressure along the line at any one instant varied in a manner similar to that shown by the wavy line of fig. 7,842.

To illustrate if extremely sensitive pressure gauges could be set up at several points in the direction in which the sound is moving it would be found that the pressure varied as indicated in fig. 7,843.

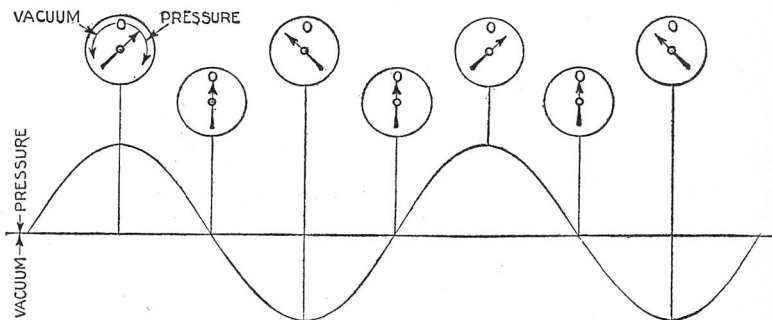


FIG. 7,843.—Diagram illustrating pressure variations due to sound waves. *It should be noted* that the type gauges shown, register pressure *above* atmospheric when the pointer moves to the right of the vertical, and *vacuum* or pressure *below* atmospheric when it moves to the left of the vertical.

Again, if a pressure gauge be set up at one point and the eye could follow the rapid vibrations of the points it would be found that the pressure varied at regular intervals and in equal amounts above and below the average atmospheric pressure. The eye, of course, cannot see such rapid vibrations, but it *can* see wave motion in water, however, which is very similar to sound waves with the exception that water waves travel on a plane surface, while sound waves travel in all directions.

In the case of water as a medium for wave propagation, if a pebble be dropped into a still pool, as in fig. 7,844, and starting at the point where the pebble is dropped, waves will travel outward in concentric circles, becoming lower and lower as they get farther from the starting point, until they are so

small as not to be perceptible, or until they strike some obstructing object.



FIG. 7,844.—Effect of throwing a stone into still water; it produces waves which travel outwardly in expanding, concentric circles from the point where the stone enters the water or point of disturbance.

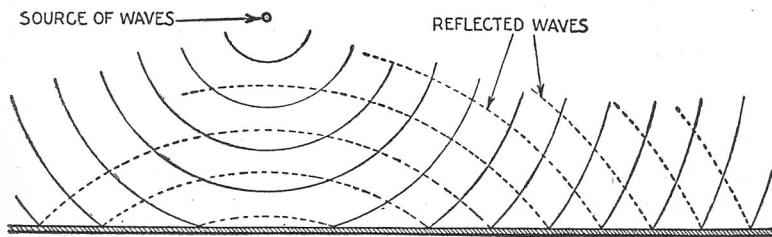


FIG. 7,845.—Reflection of waves from a plane surface.

If the pond be small it will be noticed that the waves which strike the shore will be reflected back. If the waves strike a shore that is parallel with the waves, they will be reflected back in expanding circles, as in fig. 7,845.

If the waves strike a hollow or concave shore line as in fig. 7,846 the reflected waves will tend to converge (focus) to a point.

Comparing water and air as media for wave propagation, water waves travel in *expanding circles* and air waves in *expanding spheres*.

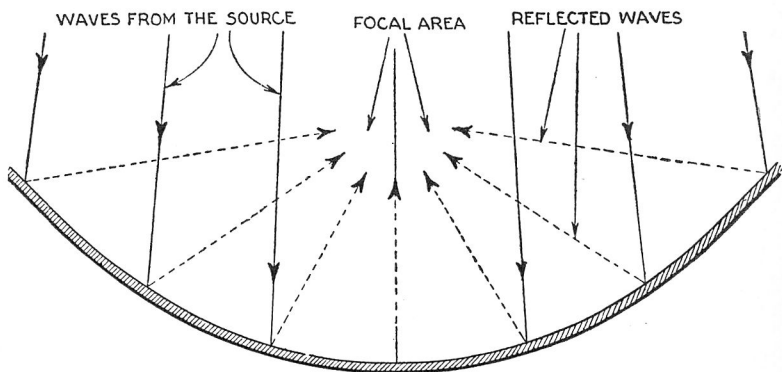


FIG. 7,846.—Reflection of waves from a curved surface. The solid lines show the direction of the original waves and the dotted lines show the direction and focusing of the reflected waves. Focusing of waves results in their reinforcement, which may cause them to build up to considerable proportion at one point.

Sound waves are reflected in a manner similar to water waves, causing echo and reverberation. If the sound waves focus at a point, loud and dead spots are produced.

Wave motion has certain definite characteristics and these characteristics determine:

1. Loudness;
2. Pitch;
3. Tone.

Loudness.—By definition, loudness is *relatively high intensity of sound*. Loudness (or amplitude) is determined by the amount of difference in pressure between the maximum compression and the maximum rarefaction. This corresponds in water waves to the vertical height of the crest above the trough of the wave. Loudness is illustrated in fig. 7,847.

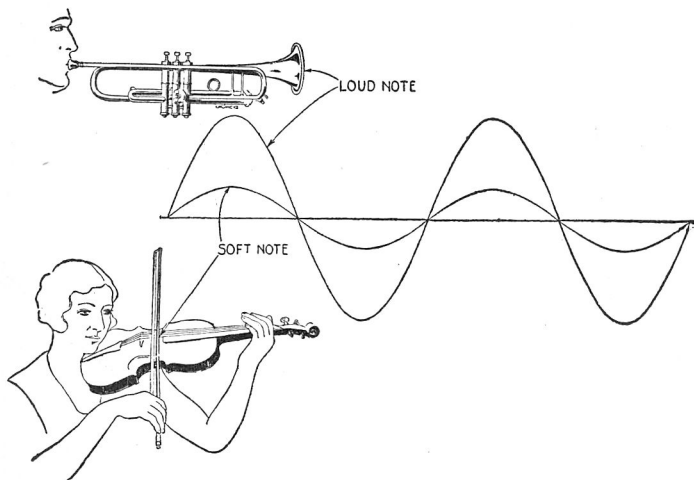


FIG. 7,847.—Properties of wave motion illustrating what causes loudness of tone.

Pitch or Frequency.—Any one of a series of variations, starting at one condition and returning once to the same condition is called a cycle. Observe some point on the surface of the water in which waves exist and it will be noticed that at this point the water will rise and fall at regular intervals. At the time at which the wave is at its maximum height the water begins to drop, and continues until a trough is formed, when it rises again to its maximum height. Accordingly, all the variations of height which one point on the surface of the water goes through in the formation of a wave, is a cycle of wave motion.

The number of cycles a wave goes through in a definite interval of time is called the frequency. Therefore the number of times

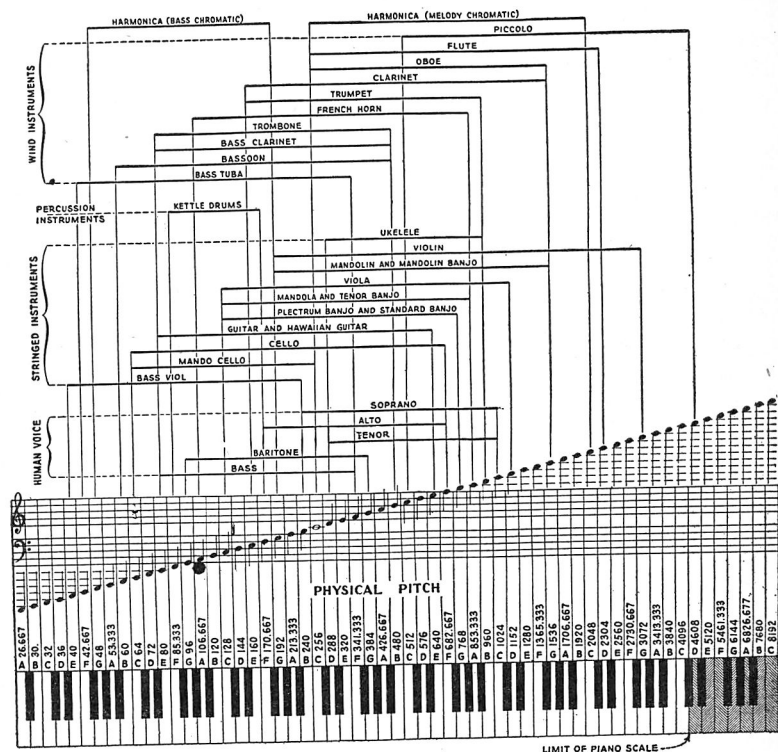


FIG. 7,848.—Musical pitch chart for piano, voice and various instruments. This chart represents the relation between the musical scale and the piano keyboard, giving the frequency of each note in terms of complete vibrations, or cycles, according to the standard used in scientific work such as the scientific scale based on middle C at a frequency of 256 cycles. The piano keyboard covers nearly the entire range of musical notes and extends from 26.667 cycles to 4,096 cycles. The piccolo reaches two notes beyond the highest note of the piano. The extreme organ range, not shown on the chart, is from 16 cycles to 16,384 cycles, scientific or physical pitch, as it is usually called. Music seldom utilizes the full keyboard of the piano, the extremely high notes and extremely low notes being seldom used. Therefore a reproducing device which reproduces all frequencies from 50 to 4,000 cycles would be satisfactory in reproducing musical notes.

the water rises or falls, at any point in one minute would be called the frequency of the waves per minute, expressed as the *number of cycles per minute*.

In sound, the number of waves per minute is large, and it is more convenient to speak of the frequency of sound waves as the number of waves per second, or, more commonly, as the number of cycles per second. Thus, a sound which is produced by 256 waves a second is called a sound of a frequency of 256 cycles.

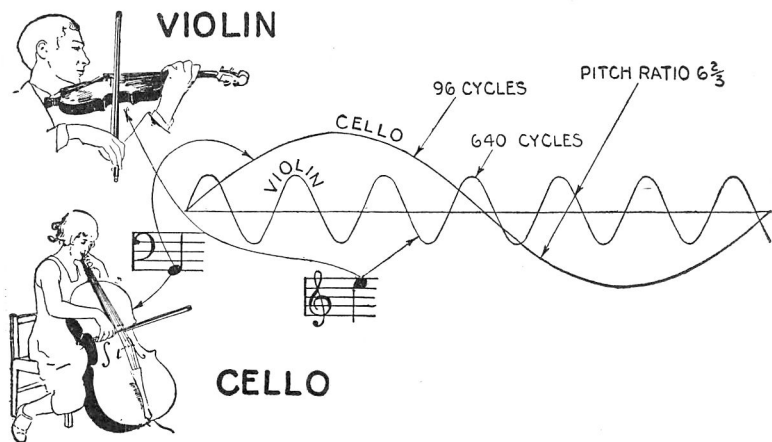


FIG. 7,849.—Properties of wave motion illustrating *pitch*.

When speaking of sound, cycles always mean cycles per second.

Considered from the standpoint of traveling waves, frequency is determined by the number of complete waves passing a certain point in one second, and this, of course, is equal to the number of vibrations per second generated at the source.

Fig. 7,848 is a chart showing pitch frequencies corresponding to the various keys of the piano and range of the human voice and various instruments.

Tone.—By definition tone is *sound in relation to volume, quality, duration and pitch*; specifically, in acoustics, a sound

that may be employed in music, having a definite pitch and due to vibration of a sounding body; opposed to sound as mere noise.

By common usage in music, tone generally means the *timbre* or *quality of sound*.

A pure note of a given pitch always sounds the same, and the frequency of this note is termed its *fundamental* or *pitch frequency*. However, notes of the same pitch from two different kinds of instruments do not give the same sound impression. This difference is due to the presence of *overtones*, sometimes called *harmonics*.

Consider again the case of a taut string which is plucked to set it in vibration.

If the string be plucked at its exact center, it will vibrate as a whole and give a very nearly pure note; but if it be plucked at some other point, say one-third of the length from one end, it will vibrate as three parts as well as a whole, and a change of tone will be noticed. If the string be plucked indiscriminately, various tones will be heard, all of the same pitch.

Hollow cavities built into the bodies of the various musical instruments give them their characteristic tones, because the air chambers, called resonance chambers, strengthen overtones of certain frequencies and give a very pronounced tone to the instruments.

Other instruments have built into them means of suppressing certain overtones, which help to give them their characteristic sounds. The frequency of an overtone is always some multiple of the pitch frequency; that is, the second overtone has twice the frequency of the pitch note, and the third overtone, three times the frequency, etc.

Overtones of twenty times the frequency of the pitch note are present in the sounds of some musical instruments, but overtones of this order are important only when the pitch note is low, because the frequency of the twentieth overtone of even a moderately high note would be beyond the ability of the human ear to detect.

Overtones give character and brilliance to music, and their presence in reproduced sound is necessary if naturalness is to be attained.

The combined result of all the partial or overtones gives the quality or timbre of the tone, that is the peculiar characteristic sound as of a voice or instrument. A great variety of tone is found in the orchestra as exemplified by the strings, wood wind, brass and reed choirs. See figs. 7,850 to 7,853.

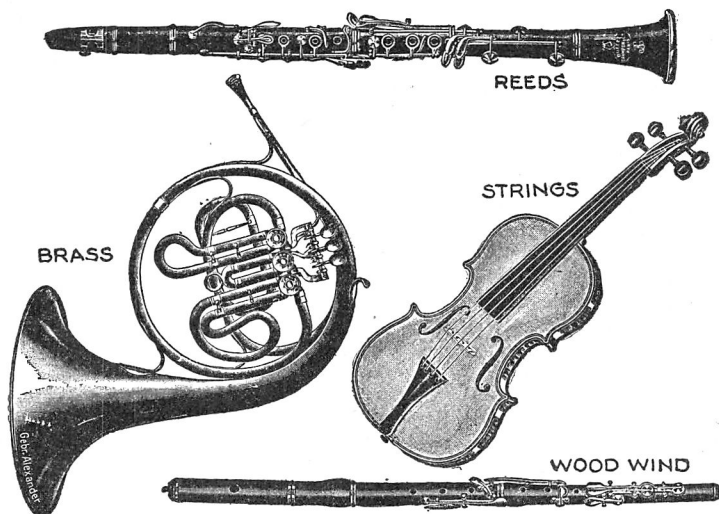


FIG. 7,850 to 7,853.—Familiar instruments of the orchestra illustrating the great variety of tone produced by the various "choirs" to which these instruments belong. It is because of this great variety of tone that the orchestra is the finest medium for musical expression. *It should be noted* that even the best organs represent a very poor attempt to imitate the orchestra—it cannot be done. Such impossible instruments as the cornet, saxophone, etc. are not employed in any legitimate orchestra.

A reproducing device which reproduces frequencies from 50 to 6,000 cycles will cover very well all the notes and overtones necessary for naturalness and distinctiveness.

In singing, the range of notes covered is approximately from 64 to 1,200 cycles, extreme limits, but this range cannot be covered by one person's

voice. The frequency of 1,200 cycles does not represent the highest frequency used in singing, because overtones of several times the frequency of the note are always present in the human voice. The presence of the overtones gives the pleasing quality to songs. This quality of the singing voice is called *timbre*. The timbre of the voice transmits the emotions of joy, sadness, etc., from the performer to the audience, and therefore is very important in the enjoyment of vocal music.

Wave Length.—By definition the wave length (of a water wave for instance) is *the distance between the crest of one wave and the crest of the next wave*. This distance remains the same as long as the wave continues, even though the wave becomes so small as to be hardly perceptible.

Frequency in wave motion is related to wave length.

All waves produced do not have the same wave length. A small pebble dropped into a pond will produce a wave of short length, but a large stone will produce a wave of correspondingly longer length. In sound the wave length is dependent upon the frequency of the source. Similarly, in sound the wave length of a sound wave is *the distance between the point of maximum compression of one wave to the point of maximum compression of the next wave*.

Sound travels at different speeds in different substances, thus it travels at a much higher speed in water and steel than in air.

NOTE.—*Voicing* is the art of obtaining a particular quality of tone in an organ pipe and of procuring uniform strength and quality throughout the entire stop. Voicing is one of the most delicate and artistic parts of the organ builder's art, and it is seldom, if ever, that a voicer is good at both flue and reed voicing.

NOTE.—*Percussion instruments* such as drums and the various accessory traps produce the greatest pressures that are used in music. Although the fundamental frequency of the notes which they emit is fairly low, the notes are particularly rich in tones of higher frequency, which may extend as high as 10,000 cycles. Although these higher tones die out rather rapidly, they are essential to good definition.

NOTE.—*The organ, piano and harp* have the greatest compass and cover a frequency range from about 16 to 4,000 cycles. All three of these instruments are characterized by a rather prominent first overtone, so that their effective range extends as high as 8,000 or 9,000 cycles.

NOTE.—*According to Prout* "the cornet is a vulgar instrument whereas the trumpet is a noble instrument." The only excuse for a cornet is that it is easier to play than a trumpet. Non-musical instruments, such as the cornet and saxophone, if they must be heard, should be confined to 2nd and 3rd rate taxi-dance halls in order that cultured and discriminating ears may not be profaned.

In the latter medium it travels about 1,100 ft. per second. An illustration of the fact that time is required for sound to travel from one place to another is shown by a steam whistle at a distance of several hundred yards. If it be observed when blown, it will be noticed that the "steam"* can be seen coming from the whistle a considerable length of time before the sound of the whistle is heard. Sounds of all frequencies, or pitches, travel at the same speed. The speed at which sound travels divided by the frequency gives the wave length of the sound wave.

A knowledge of wave length is necessary for the proper construction and location of baffle boards and horns in theatres.

Speech.—The sounds of speech are divided into two classes, vowels and consonants. The vowel sounds are used in the pronunciation of the letters *a, e, i, o, u*, and sometimes *y*, in the formation of words.

These letters are also used in combination to indicate other vowel sounds. The pitch frequencies of the vowel sounds in male voices range from 110 cycles to 140 cycles. For female voices the range is from 230 to 270 cycles. The characteristic frequencies, or overtones of the vowel sounds, however, reach frequencies of 3,300 cycles. So important are these overtones that the pitch frequency can be entirely eliminated without noticeably changing the sound sensation produced on the human ear. The full range of frequencies used in vowel sounds is from 110 cycles to 4,800 cycles.

The pitch frequency of the vowel sounds are produced when air is blown through the vocal cords.

The vocal cords are two muscular ledges in the air passage of the throat. When these muscles are taut there is a narrow slit between them, which sets the air passing through into oscillation. The sound produced by the vocal cords is changed by the cavities of the mouth.

The shapes of the cavities continuously change as a person speaks, making it possible for him to produce a wide variety of sounds, all of very nearly the same pitch frequency.

*NOTE.—The *white cloud* seen issuing from a steam whistle usually called "steam," is not steam but a fog of minute liquid particles produced by *condensation*. The term is misused above simply for convenience. Steam is invisible.

Consonant sounds are usually produced without the aid of the vocal cords.

Most of these sounds are produced by the lips and teeth, as in the pronunciation of *th*, *s*, and *f*. The range of frequencies covered by consonant sounds is from 200 to 8,000 cycles, but most consonant sounds have frequencies of less than 6,000 cycles.

Hearing.—The actual mechanism of hearing is not very well understood, but certain facts regarding the ability of the ear to register sounds of various frequencies has been determined very accurately.

The range of frequencies which the average person can hear is from about 20 cycles to 17,000 cycles, but a comparatively large amount of sound energy is required before the ear can detect sound of extremely low or extremely high frequencies.

The ear is most sensitive to frequencies between 500 cycles and 7,000 cycles; also, the ear is most sensitive to changes of pitch and changes of intensity of sound in this same band of frequencies.

NOTE.—*Woman's speech* in general is more difficult to interpret than man's. This may be due in part to the fact that woman's speech has only one half as many tones as man's, so that the membrane of hearing is not disturbed in as many places. It may be inferred therefore that the nerve fibres do not carry as much data to the brain for interpretation. The greatest differences occur in the case of the more difficult consonant sounds. In woman's speech these sounds are not only fainter but require a higher frequency range for interpretation. A range of from 3,000 to 6,000 cycles for man's voice corresponds roughly to a range of from 5,000 to 8,000 cycles for woman's voice. Since the ear is less sensitive in the latter range and the sounds are initially fainter, their difficulty of interpretation is greater.

NOTE.—When sounds containing a number of tones are increased in loudness, the lower tones in the sound deafen the auditor to the higher tones. This deafening or masking effect becomes very marked when the sound pressure of the lower tones is greater than twenty sensation units. In the case of speech, this effect impairs the interpretation of the higher pitched sounds. The best loudness for the interpretation of speech corresponds to a sound pressure between 0 and 20 sensation units. If the sound pressure be less than this, the fainter sounds are inaudible. If the sound pressure be greater, the masking effects impair the interpretation of these sounds.

TEST QUESTIONS

1. *How is sound produced?*
2. *Explain the propagation of sound.*
3. *Draw a diagram illustrating pressure variations due to sound waves.*
4. *What is the effect of throwing a stone into still water?*
5. *How are sound waves reflected?*
6. *What are the characteristics of wave motion?*
7. *Upon what does loudness depend?*
8. *Define pitch or frequency.*
9. *How are sound cycles measured?*
10. *What is tone in music?*
11. *What is the effect of overtones or harmonics?*
12. *Why are hollow cavities built into the bodies of various musical instruments?*
13. *What is the range in cycles of the human voice?*
14. *Define the term wave length.*
15. *What is voicing?*
16. *What musical instruments produce the greatest pressures?*
17. *What is the difference between a cornet and a trumpet?*
18. *Into what two classes are the sounds of speech divided?*
19. *Why is woman's speech more difficult to interpret than man's?*

CHAPTER 195

Synchronized Sound

In order to reproduce in a théâtre the pictorial record of events accompanied by the sound associated with those events, it is, of course, necessary to add equipment to that installed to produce only the silent motion picture.

Methods of Recording Sound.—There are two basic methods of sound recording:

1. Cutting a groove in a wax disc;
2. Making a photographic impression on film.

Formerly in making disc records the original sound energy of the source was used to actuate the stylus or cutting point the same as in making an ordinary phonograph record.

The present method used by all up to date record producers employs electricity. The sound energy is first converted into electrical energy, amplified in vacuum tube amplifiers, and the electrical energy is then used to actuate the mechanism which cuts the impression on the record. With this method no sacrifice in faithfulness is necessary to obtain the desired volume, with the result that extremely faithful reproductions are now possible from disc.

The methods of recording on wax discs by different producers are very similar although there are slight differences in the apparatus used.

There are two fundamentally different methods of recording on film as by:

1. Variable area;
2. Variable density.

Variable area recording is used by Photophone and variable density by Western Electric and Movietone.

Picking Up and Converting Sound Energy.—The first step in recording, the *picking up* of the sound energy and converting it into electrical energy is essentially the same in all modern recording systems. This is done by means of a sensitive microphone. The RCA Photophone, the Western Electric and Fox Movietone all use a condenser microphone similar to those used in radio broadcasting.

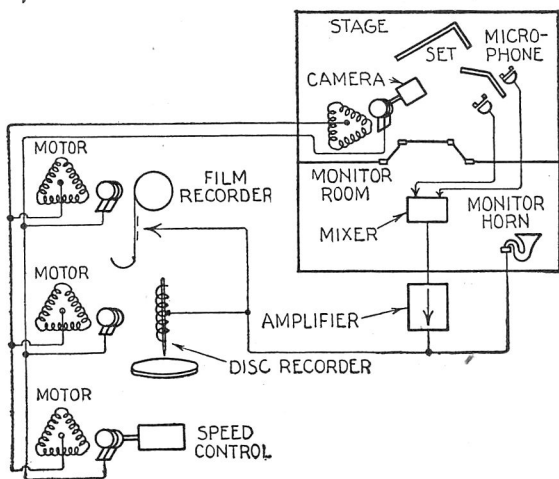


FIG. 7,854.—Studio sound recording system in its simplest form. The essential parts of such a system consist of microphone pick ups on the stage, a mixer and volume control in the monitor room, system and monitor amplifiers, recording machines, and a synchronous motor system for synchronizing the recorders with the cameras.

When a condenser microphone is acted upon by sound waves the diaphragm moves in and out at the frequency of the sound waves. A pressure of 180 volts *d.c.* is impressed across the plates and a resistor of 20 to 50 million ohms resistance is in series with one of the leads. As the diaphragm is moved in and out by the action of the sound waves, the alternating current

set up flows through the resistor and produces an alternating voltage across it. This alternating voltage is impressed on the grid of the first tube of a vacuum tube amplifier. The amplified signals are then used to operate the recording device.

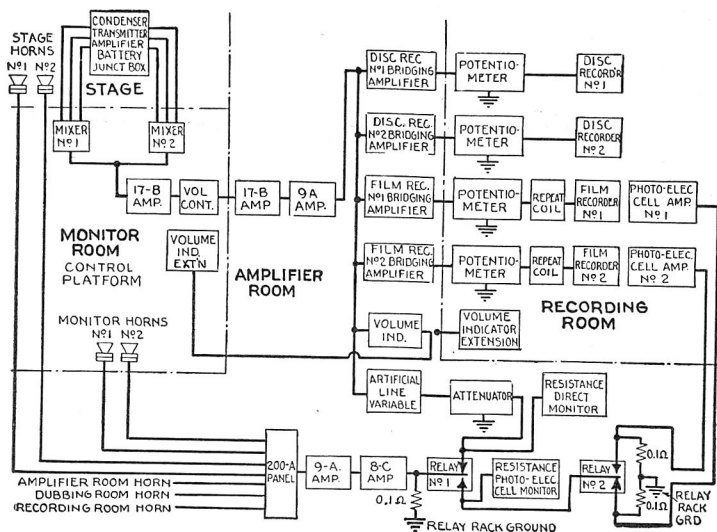
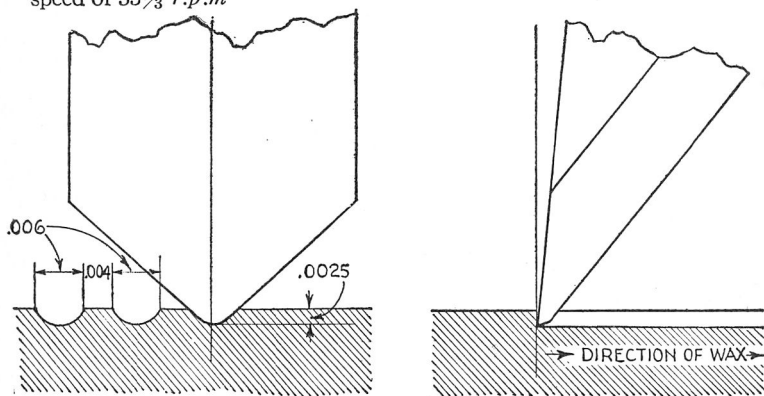


FIG. 7,855.—One complete recording channel.

***NOTE.—Method of making wax record duplicates.**—The wax is coated with a fine powder of conducting material. It is then electro-plated so as to give a metallic negative record called a *master*. This master is again electro-plated after the surface has been suitably treated to permit an easy removal of the resultant positive plate. This positive is commonly called an *original*. From the positive another negative is made, a metal mold called a *stamper*. From it duplicate originals can be plated to make duplicate stampers. These successive plating processes involve no measurable injury to the quality of the record. By the custom of making a number of duplicates, the master is protected from accidents and wear to which it would be subject if used to make the finished record. The stampers are used to press the final product, and as many as a thousand records can be made with one stamper. The material from which the records are made is called *record stock*. This material must have a hard surface to resist wear, and must contain enough abrasive, or wear producing material, to grind the needle quickly to a good fit. At the beginning of a run of a new needle the pressure on the record is very great because of the small area of the needle point. However, after a minute's wear the needle pressure is reduced to 50,000 lbs. per sq. inch.

Disc Recording.—The amplifier just described actuates a vibrating armature which has attached to it a sapphire stylus or cutting point.

This stylus is placed on the surface of a rotating plate and cuts a wavy groove in its surface. This plate, while usually referred to as a wax plate, is in reality made of an insoluble soap. The plate is rotated at a constant speed of $33\frac{1}{3}$ *r.p.m*

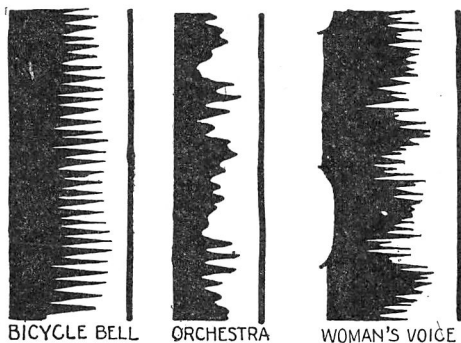


FIGS. 7,856 and 7,857.—Recorder stylus. The shape of the groove varies somewhat in commercial practice. The groove and stylus here shown is that most commonly used with Western Electric apparatus. The groove is approximately .006 in. wide and .0025 in. deep. The pitch of the groove is between .010 in. and .011 in. so that the space between grooves is about .004 in. Thus the maximum safe amplitude is about .002 in. If this occur at 250 cycles the corresponding amplitude at 5,000 cycles, assuming constant absolute intensity of sound over this range, would be .0001 in. It is important that a smooth groove be cut as any roughness in the walls introduces extraneous noise in the reproduced sound. To insure a truly smooth groove the surface of the wax must be shaved to a high polish. The texture of the wax must be fine and homogeneous which requires not only that the wax composition be correct, but that it be operated at the proper temperature. Fig. 7,856 a radial section through the wax; fig. 7,857 a section looking from stylus point to the center of the disc.

Synchronizing Sound on Disc.—After making a wax disc, it is rotated at a uniform speed of $33\frac{1}{3}$ *r.p.m.* and is driven by a synchronous motor. The camera is driven so as to have a film speed of 90 ft. per min. by another synchronous motor operating from the same power supply as the motor which drives the wax disc. The recording disc and the camera are

started at the same time, and after they get up to speed they are operated simultaneously. Since both are driven by synchronous motors they will always have the same relative speed. Therefore, the sound and picture will always be in synchronism when produced if the film and disc be both started at the proper start position, and there be no mishap such as the needle of the pick up jumping the groove, or the film breaking and not being properly patched.

Should the film break, it is necessary to have the same number of frames in the patched film as it had originally, if the sound and picture are to remain in synchronism. The addition of blank film to replace parts of the film which were torn results in disagreeable breaks in the picture.



FIGS. 7,858 to 7,860.—Details of “sound track” with *variable area* method of recording. The juncture of the opaque and transparent parts of the sound track form a wavy line which is practically an exact representation of the sound pressures of the original sound waves.

Variable Area Method of Recording on Film.—The system consists essentially of:

1. A source of light;
2. A mirror;

Which is vibrated by the amplified sound currents.

3. A suitable optical system for concentrating the light into a very fine beam.

The intensity of the light is kept at constant value, but the area of the sensitized film which is affected by the light is varied.

The elements of the system are shown in fig. 7,861.

A beam of light from an incandescent lamp is focused on the mirror. The vibration of the mirror sends the light across the exposed moving film through a suitable optical system containing lenses and a narrow slit. The mirror needs to move only a little to sweep the light beam comparatively large distances at the film.

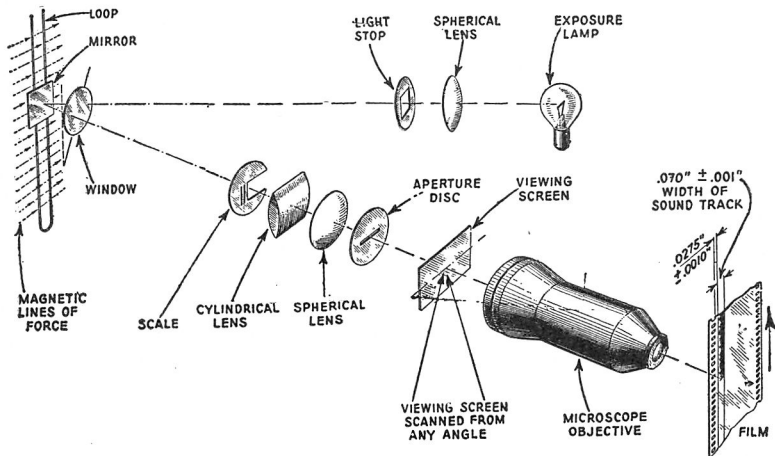


FIG. 7,861.—Elements of *variable area* method of recording on film. *In operation*, when the mirror is at rest only one half of the sound track is exposed. The other half of the light beam is cut off by a screen. When the mirror is moved to its extreme position in one direction, the light beam is shifted off to the screen so that the beam covers the entire sound track. When moved in the other direction to its extreme position, the beam moves over so that it is cut off entirely by the screen and strikes no part of the sound track. When referring to the extreme position which the mirror moves it is not meant that this extreme is the maximum movement which can be obtained by the mirror, but only the maximum position to which it should ever move when recording. When the film moves through the recorder it is exposed to this fine line of light which varies in length as the mirror vibrates in response to the sound currents flowing through the loop supporting it. When the film is developed the part of the film which was exposed to the light beam will be opaque while the remainder of the sound track will be transparent, as shown in figs. 7,858 to 7,860.

The light from the lamp is focused through a condensing lens on to the mirror of the galvanometer. The light stop between the lens and the mirror cuts off the fringe of distorted light so as to give a clear cut beam of light.

The galvanometer window is tilted at a slight angle to keep the light reflected from its surface from entering the optical system. The reflected light from the mirror passes through the cylindrical lens, which condenses the light in one direction only. It then passes through a spherical condensing lens which reduces the beam size still more.

The beam from this lens is focused on the slit in the aperture plate, this slit being .003 of an inch wide. The light which passes through the aperture plate slit is focused on the film through a microscope objective lens system. This objective reduces the size of the beam by a 4 to 1 ratio in both directions so that the resultant beam on the film is .070 of an inch long by .00075 of an inch wide.



FIG. 7,862.—Film showing sound track with *variable density* method of recording.

Variable Density Method of Recording a Film.—There are two different methods of variable density recording, as with:

1. Variable intensity light,

Called “aeolight” and used by Fox Movietone.

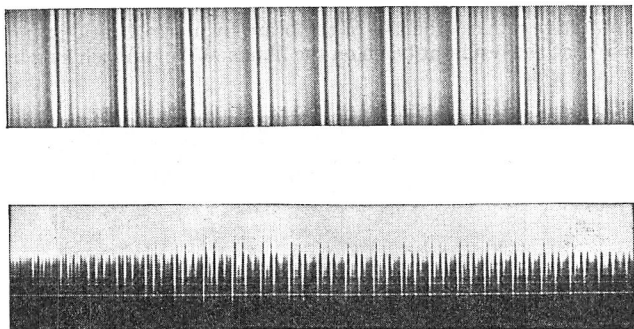
2. Light valve.

In the variable intensity light method, the light varies in intensity with the amplified sound currents and shines through

a narrow slit on to the moving film, which is kept running at a constant speed of 90 ft. per minute.

The slit is cut into a small quartz block held in contact with the moving film. This quartz block is coated with silver to make it opaque, and the slit is engraved in the metal to the desired size.

When the film is developed after being exposed to the variable intensity light, the sound track will be made up of lines of varying density extending across the sound track as shown in fig. 7,863.



FIGS. 7,863 and 7,864.—Comparison of sound tracks showing difference between the variable density, fig. 7,863, and fig. 7,864, variable area methods of recording.

The spacing of these lines at each point depends on the pitch of the sound which was recorded at that moment.

The difference in density of the lines depends on the loudness of the sound, that is, the greater the contrast between light and dark lines, the louder the sound.

The light valve method is used in the Western Electric system. The light valve in this case varies the amount of light by the opening and closing of a slit. This slit is the space between two taut sides of a loop of wire suspended in a magnetic field. As the sound current passes through the loop, the loop opens and closes passing varying amounts of light through it. This light is then focused with lenses on the moving film so as to form lines of varying density when the film is developed. The light valve is shown in fig. 7,865.

When the valve is interposed between a light source and a photographic film it virtually forms a camera shutter of unconventional design. With this system, recording in the studio is carried out on a film separate from that

which receives the picture. This practice permits the use of two machines to make duplicate sound records, an insurance which is well worth its cost. The practice of separate negatives for sound and picture also permits the picture negative to be developed and printed according to well established technique, and allows the necessary latitude in developing the sound record. The recording machine is shown in fig. 7,866.

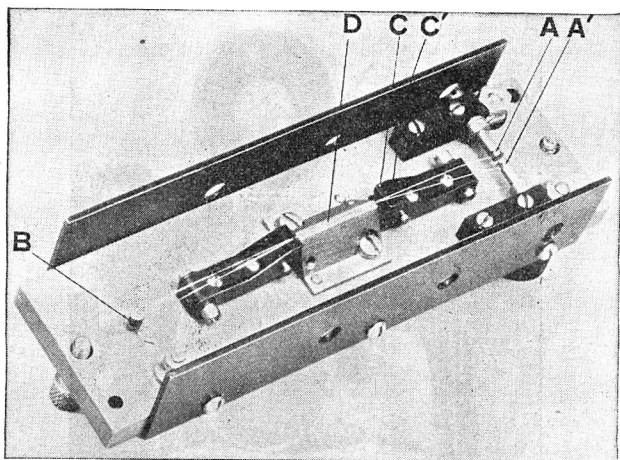


FIG. 7,865.—Light valve for variable density film recording. *It consists of* a loop of durium tape suspended in a plane at right angles to a magnetic field. When the assembly of magnet and armature is complete, the two sides of the loop constitute a slit, .002 by .256 in., its sides lying in a plane at right angles to the lines of force and approximately centered in the air gap. The ends of the loop are connected to the output terminals of the recording amplifier. If the magnet be energized and the amplifier supplies an alternating current, the loop opens and closes in accordance with the current alternations. When one side of the wave opens the valve to .004 in. and the other side closes it completely, full modulation of the aperture is accomplished. A,A', windlasses; B, spring held pulley; C, C' insulated pinners; D, armature.

Synchronizing Sound on Film.—As just mentioned the sound film is usually run on a separate machine from the camera for practical reasons, and the two films must be so synchronized that when they are printed together they will be in synchronism throughout the length of the film. This is accomplished by running the camera and the recorder at exactly the same speed. They are both driven by synchronous motors connected

to the same power supply, and this keeps them always in synchronism.

Some kind of marking is required so that the picture and sound track can be lined up for printing. This is sometimes taken care of by marking the

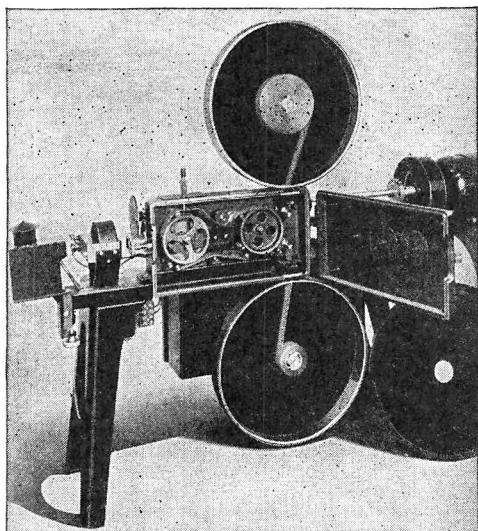


FIG. 7,866.—Studio recording machine with the door of the exposure chamber open. The left hand sprocket engages twenty perforations and is driven through a mechanical filter. The recording machine is driven by a motor synchronously with the camera. Lest there be any variation in the velocity of the film past the line of exposure, the sprocket which carries the film at that point is driven through a mechanical filter which holds the instantaneous velocity constant to one part in one thousand. In the recording machine a photo-electric cell is mounted inside the left hand sprocket which carries the film past the line of exposure. Fresh film transmits some four per cent of the light falling on it, and modulation of this light during the record is appreciated by the cell inside the sprocket. This cell is connected to a preliminary amplifier mounted below the exposure chamber, and with suitable further amplification the operator may hear from the loud speaker the record as it is actually being made on the film.

film by means of a small marker lamp which shines on the film outside of the sprocket holes. Since the sound head of the projector is 19 frames from the picture in the frame, it is necessary to displace the sound track by 19 frames when they are printed together.

The advantages of sound on film is that, if the projector be properly threaded, the sound will always be in synchronism with the film. The breaking of the film does not interfere with the synchronous action, so that a blank patch is not necessary.

Synchronous Reproduction of Recorded Sound.—The first step in synchronous reproduction is to *generate a small electric current whose variations correspond to the sound waves forming*

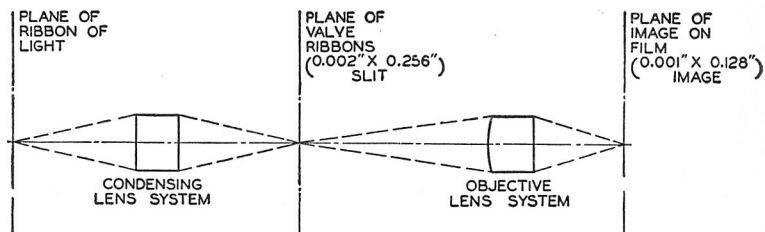


FIG. 7,867.—Optical system for studio recording. At the left is a light source, a ribbon filament projection lamp, which is focused on the plane of the valve. The light passed by the valve is then focused with a two to one reduction on the photographic film at the right. A simple achromat is used to form the image of the filament at the valve plane, but a more complicated lens, designed to exacting specifications by Bausch and Lomb, is required for focusing the valve on the film. The undisturbed valve opening appears on the film as a line .001 by .128 in., its length at right angles to the direction of film travel. The width of this line varies with the sound currents supplied to the valve, so that the film receives exposure to light of fixed intensity during the varying time required for a given point to traverse the varying aperture of the slit.

the voice or music that was recorded. Depending upon which of the two general methods of recording was used, this current is obtained either from an electrical reproducer playing on a disc record, or from a film reproducing attachment through which the film passes on leaving the projector head.

The disc records employed are similar to the best types of phonograph record except that they are much larger and run at about half standard speed; this enables each record to play throughout a whole reel. The film used with the disc record, called a *synchronized film*, is similar to an ordinary

film, except that one frame at the beginning is specially marked to give the starting point.

With the film method, the sound record consists of a *band about $\frac{1}{8}$ in. wide, called the sound track, which runs down one side of the film and having photographed on it microscopic lines as previously described and shown in fig. 7,862.*

Such a film is called a sound film, and is otherwise similar to an ordinary film. After leaving the lower sprocket of the projector head, the sound film enters the reproducing attachment, as in fig. 7,868 where it passes over a sprocket that moves it along at constant speed.

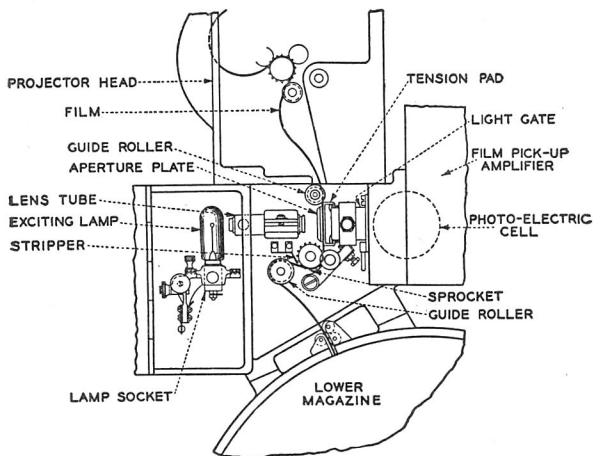
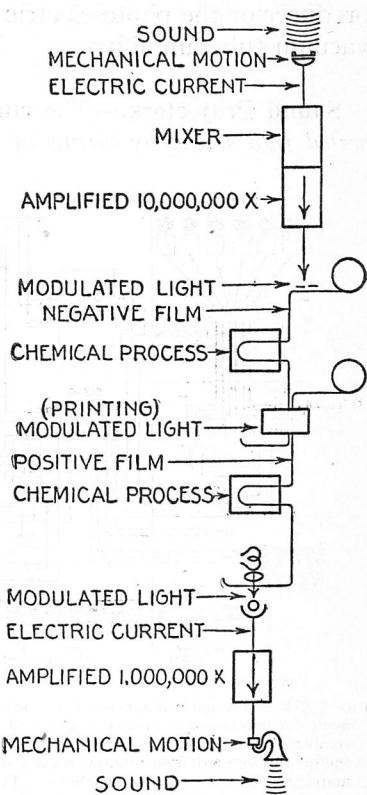
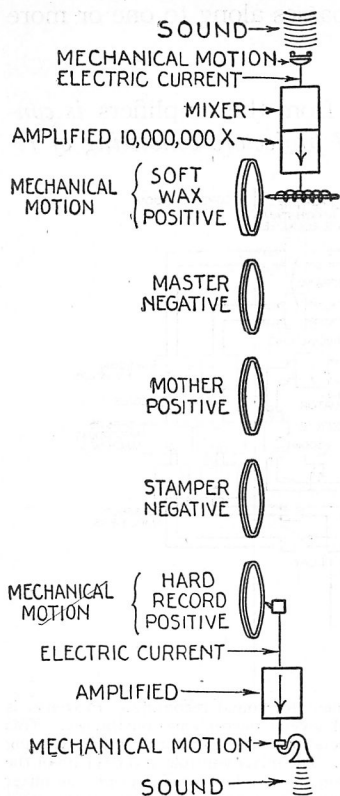


FIG. 7,868.—Detail of motion picture projector head and *sound head* for reproducing sound from film.

A narrow bright beam of light from a high intensity exciting lamp is focused on the sound track of the film through a system of lenses and an aperture plate. The light which has passed through the moving film will then vary in intensity according to the variations of the lines recorded on the sound track. This light falls on a photo-electric cell, which produces a small electric current whose variations correspond to the light, and therefore to the sound which was recorded.



FIGS. 7,869 and 7,870.—Recording and reproducing sound, showing intermediate processes. Beginning as sound waves, mechanical motion is imparted to the diaphragm of the condenser transmitter. This mechanical motion is in turn translated into a minute electric current. After being amplified the power of this current modulates a light to which film is exposed. The resultant latent image is treated chemically and when developed, again modulates a light to produce the positive. After development this positive, when run through a projector, modulates a beam of light, thereby controlling a minute electric current. After amplification the resultant power is sufficient to impart mechanical motion to a loud speaker diaphragm, thereby producing a very close approximation to the original sound. Beginning as sound, fourteen changes of condition must be passed through before the sound is reformed. The same number of changes occur in recording on disc.

Amplification.—The small current from the electrical reproducer or the photo-electric cell passes along to one or more vacuum tube amplifiers.

Sound Projectors.—The current from the amplifiers is converted into sound by means of sound projectors consisting of re-

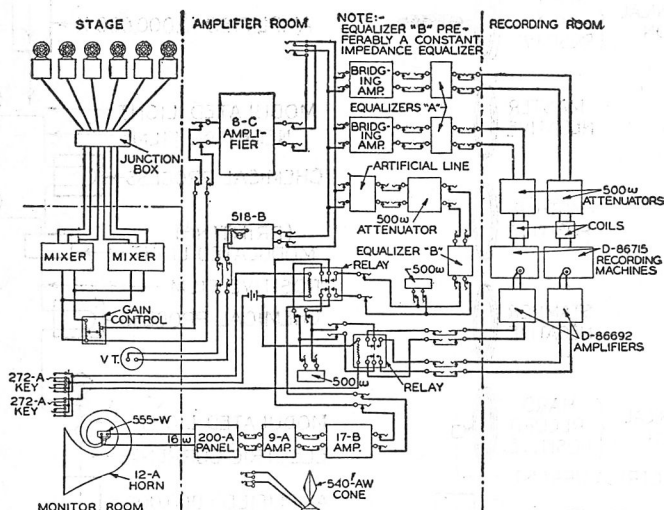


FIG. 7,871.—Schematic diagram of a studio equipment for sound recording. Provision is made for combining if desired the contributions of several microphones on the set. This combination is under the control of the mixer operator in the monitoring room, viewing the set through a double window in the studio wall. The mixer controls also the gain of the amplifiers for the recording machines. The diagram shows relays which permit the mixer to connect the horn circuit either directly to the recording amplifier or to one or the other of the monitoring photo-electric cells in the film recorders. The direct connection is used in preparing the sound pick up in the studio; the program is rehearsed until satisfactory arrangement of microphones and of amplifier gain is effected. The electrical characteristic of this direct monitoring circuit is so designed that the sound quality heard in the horns shall be the same as the quality to be expected in the reproduction of the positive print in the theatre.

ceivers and horns located at the screen, as shown in figs. 7,872 and 7,873.

The number of horns used, and their exact location depends on the size and acoustic properties of the house. Usually a special type of screen is employed, which reflects light well and enables a good picture to be obtained and is translucent for sound waves.

The horns are placed immediately behind the screen so that a perfect illusion that the voice or music is coming from the speakers and artists seen on the screen is obtained in all parts of the house.

Obviously if the sound be not coming directly from the screen, the illusion is lost.

The horns used in all these systems can be mounted in such a manner that they are removable whenever the stage is used for purposes other than pictures. This can be done either by flying them or by mounting them on towers that are easily and quickly removable.

TEST QUESTIONS

1. *Name two methods of recording sound.*
2. *Describe the two methods of recording sound on film.*
3. *How is sound energy picked up?*
4. *Describe the method of making wax record duplicates.*
5. *Explain disc recording.*
6. *How is sound synchronized on disc?*
7. *Define the term sound track.*
8. *What are the two methods of recording on film?*
9. *Describe in detail the variable area method of film recording.*

10. *Make a sketch illustrating the elements of the variable area method of recording on film.*
11. *Explain in full the variable density method of recording on film.*
12. *What is the comparison of sound tracks made by the two methods?*
13. *Of what does a light valve consist?*
14. *How is sound synchronized on film?*
15. *What are the advantages of sound on film?*
16. *What is the first step in synchronous reproduction of recorded sound?*
17. *Describe in full the method of reproducing recorded synchronized sound.*
18. *Draw a diagram showing all the apparatus used in reproducing synchronized recorded sound.*

CHAPTER 196

Sound Reproducing Equipment

In theatres in which motion pictures accompanied by synchronized speech or music are presented, there must be in addition to the sound box or disc turntable, additional apparatus to amplify the current, to effect its conversion into sound and so to direct the sound into the theater auditorium, as to create the illusion that it emanates from, rather than merely accompanies, the picture.

When a theater is being prepared for presenting sound pictures, the film projectors in use are ordinarily retained but each is fitted with a new motor and driving mechanism; it is provided with a turntable and electric pick up for disc records, and with analogous equipment for film records, or both.

Typical installation layouts for sound pictures are shown in figs. 7,872 and 7,873. A layout consists of:

1. Film and disc.

These are reproducing attachments, by means of which, small electric currents are generated with variations corresponding to the sound waves produced in recording.

2. Vacuum tube amplifiers.

These greatly magnify the electric currents.

3. Sound projectors.

These consist of receivers and horns which convert the electric energy into sound.

Disc Record Pick Up.—The pick up used for disc records, is in some ways similar to the reproducer of an ordinary acoustic

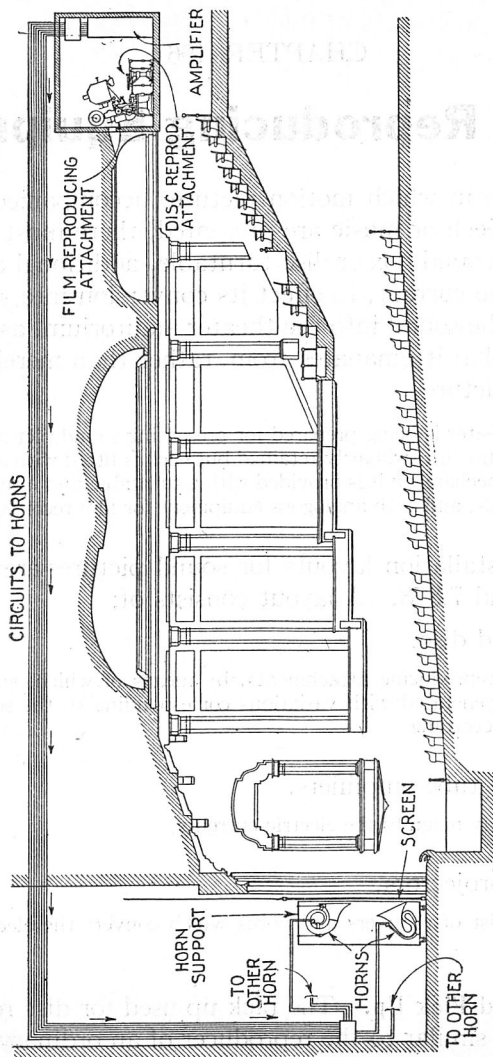


FIG. 7,872.—General installation layout of sound reproducing equipment.

phonograph, with a needle holder connected to a clamped diaphragm of highly tempered spring steel. To the diaphragm there is fastened an armature made of a special high permeability alloy, so arranged that as the diaphragm and the armature vibrate, the flux in the air gap of a permanent magnet varies correspondingly; in appropriately placed coils, currents are induced which are the electric representation of the wave groove which moves past the needle.

Although this instrument delivers energy at a comparatively low level, it has a nearly uniform response over a wide range of frequencies. That result has been secured largely by preventing distortion which would arise from resonance in any part of the system; the members have been designed with

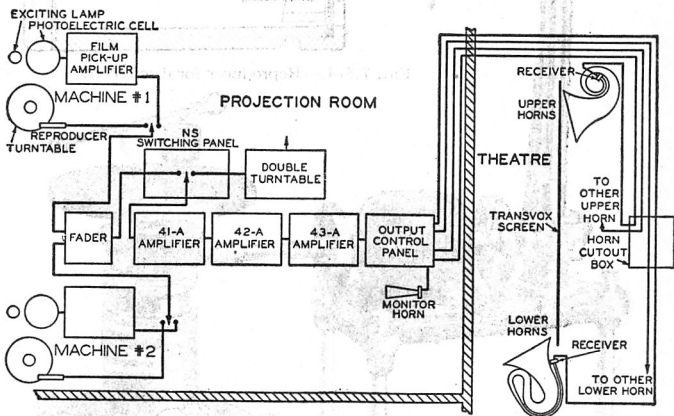


FIG. 7,873.—Layout of a typical theatre for presenting sound pictures. The amplifier is built in three units, of which the first consists of three low power tubes connected in tandem, resistance coupled, with the filaments heated by a twelve volt battery. In the second unit there are two medium power tubes with a push-pull connection, whose filaments are heated by low voltage alternating current. Two similar tubes in this unit act as a full wave rectifier, and supply rectified *a.c.* for the plate circuits of the amplifier tubes in the first and second units. The third unit has a single stage of high power push-pull amplifier tubes and push-pull rectifier tubes; like the second, it operates entirely on *a.c.* The three units can be arranged to meet any conditions. In small theatres only the first two are required, and in larger houses the high power unit, the third is used as well. For unusual conditions two or more of the high power units may be operated in parallel from the output of the second unit to give a greater volume of sound.

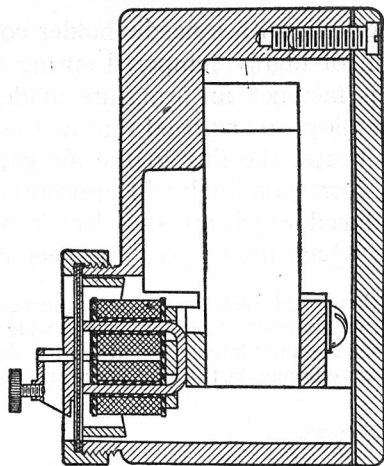


FIG. 7,874.—Reproducer for disc record.

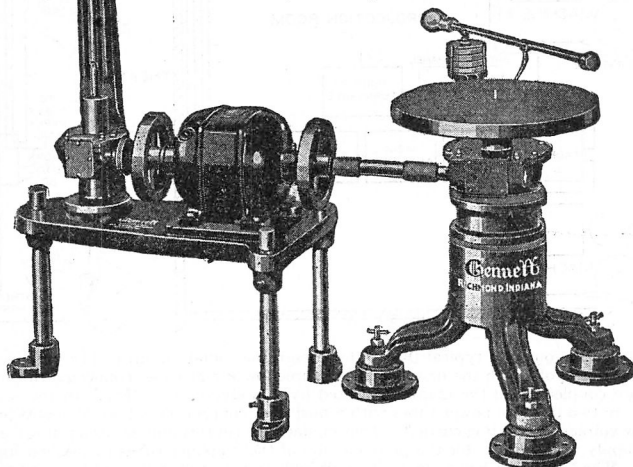


FIG. 7,875.—Gennett synchronizer designed for use with various projectors. A.c. synchronous motor drive which insures constant speed of the disc so that when the disc is synchronized with the film it remains in synchronism. Upright arm is adjustable for height of various types of projectors. Synchronizer may be used to play $33\frac{1}{3}$ r.p.m. records for intermission music and non-synchronous films.

natural periods beyond the range of frequencies to be transmitted, and the magnet chamber back of the diaphragm is filled with a heavy oil to damp free vibration.

The films used with the disc records, called synchronized films, differ from ordinary films only in that one frame at the beginning of each is marked to give the starting point.

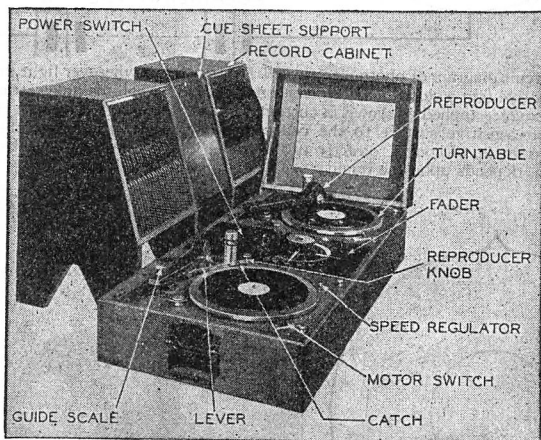


FIG. 7,876.—Non-synchronous double turntable cabinet for disc reproducing where records are not synchronized with the film. Each turntable is provided with a pick up and means for locating it accurately upon a record, and a fader to make possible continuous playing. The same amplifier and loud speakers are used as for the synchronized speech and music.

Photo-electric Cell.—This is a device which varies in electrical resistance *in proportion to the amount of light falling upon it*. Manufacturers of photo-electric cells used for sound pictures make use of the fact that when light falls upon the surface of a metal, electrons are emitted from its surface. Although all metals emit electrons when subjected to light, only a few of them are affected by ordinary or visible light. The number of electrons emitted is *directly proportional to the amount of*

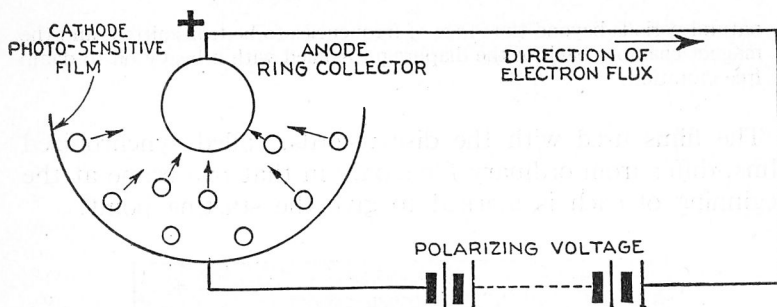


FIG. 7,877.—Circuit diagram of photo-electric cell. *In operation* wherever light flux falls upon the photo-sensitive film a cloud of electrons is emitted and if there be an electric field, called the *polarizing voltage* applied as shown, a current will be caused to flow as each electron flows from the photo-sensitive surface to the collector and deposits its charge thereon. This amount of current is, of course, directly proportional to the number of electrons emitted, which, in turn, depends upon the quality of the photo-sensitive film.

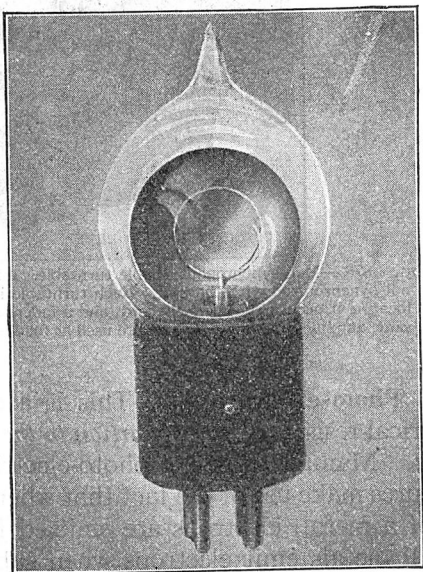
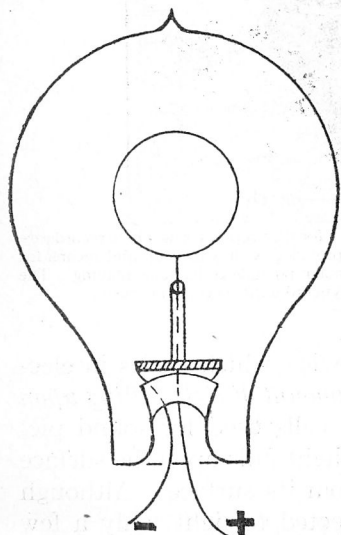


FIG. 7,878 and 7,879.—Jenkins type SR1 photo-electric cell. It is gas filled and suitable for sound moving picture work relay operation; also for television direct pick up work when the ionization voltage is properly chosen.

light falling on the surface of the metal; that is, if a certain amount of light fall upon the surface of the metal, a definite number of electrons will be emitted, and if the amount of light falling on the surface be doubled, the number of electrons emitted will also be doubled.

In order to make use of this fact some method of collecting the electrons emitted is necessary. To obtain this end a plate coated with the active metal is placed within a vacuum tube and an electrical connection is made from it to the outside of the tube. Another conductor set in the proximity of the plate is also placed within the tube and has a lead brought out for electrical connection.

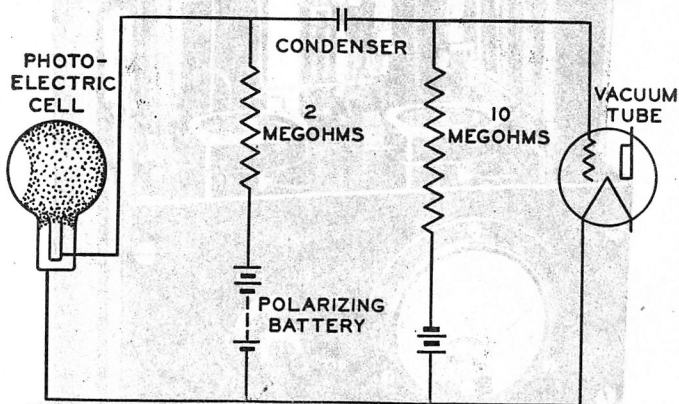


FIG. 7,880.—Photo-electric cell. The characteristic of this device is that when it is polarized by a proper voltage and is used within proper limits the current through it is proportional to the incident light.

The plate or metallic surface coated with the active metal is called the *cathode*, and the other conductor is called the *anode*.

If the cathode be connected to the negative side and the anode to the positive side of some source of *d.c.* voltage, such as a battery, the anode will collect the electrons emitted from the cathode.

Since the number of electrons emitted depends upon the amount of light falling on the cathode, the number of electrons

collected by the anode will vary with the amount of light falling on the cathode.

The electrons collected by the anode do not remain there, but flow off immediately in the form of an electric current through the external circuit and return to the cathode. Therefore, a varying amount of light falling on

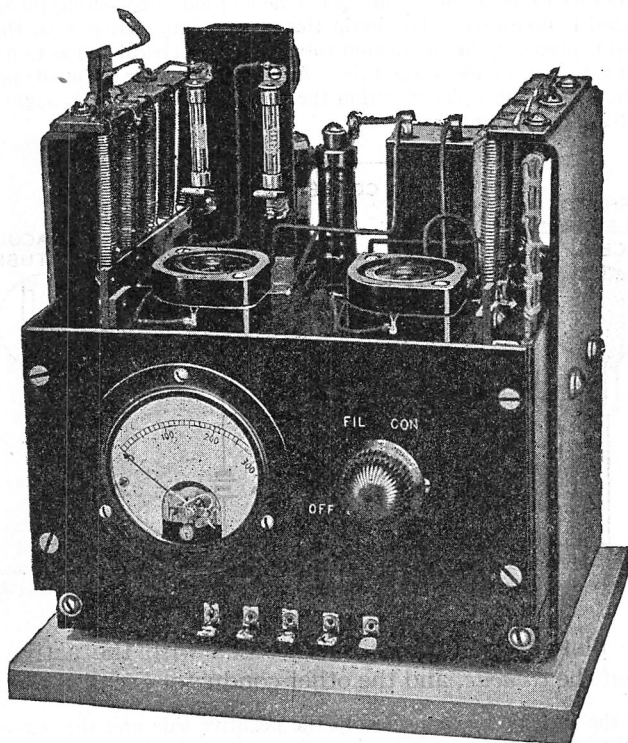


FIG. 7,881.—Photo-electric cell amplifier for projector. *In construction* the cell and amplifier are enclosed in a heavy metal box made fast to the frame of the projector, and the frame is carefully grounded. As a further precaution, the amplifier is supported within the enclosing box by a rather elaborate flexible suspension, lest vibration of the vacuum tubes introduce noise components into the current. The amplifier brings up the energy level to about that obtained from the magnet coils of the reproducer for disc records.

the cathode will cause a varying current in the external circuit. A photo-electric cell of the type used is shown in fig. 7,878 and the circuit in fig. 7,880.

When polarized by a proper voltage, the cell passes a current proportional, within limiting values, to the intensity of the light falling upon it.

The polarizing voltage is supplied to the cell through such a high resistance that in operation there is obtained from the cell a voltage across the resistance proportional to the incident light. The voltage bears therefore at any time an inverse relation to the density of that part of the sound track then between the exciting lamp and the cell.

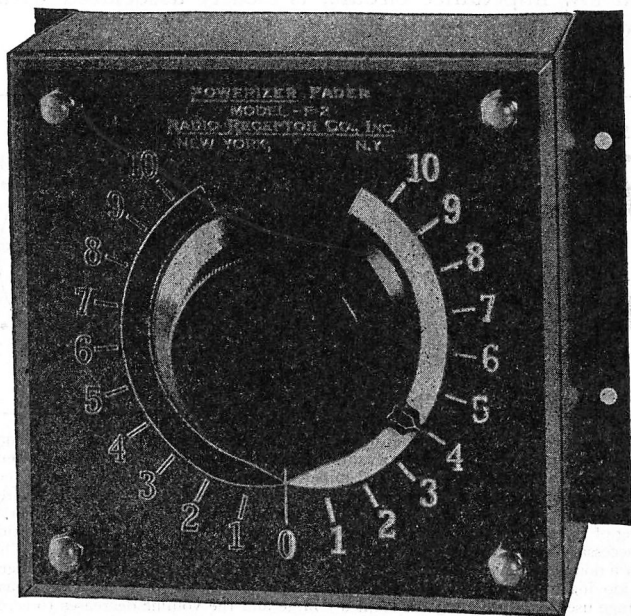
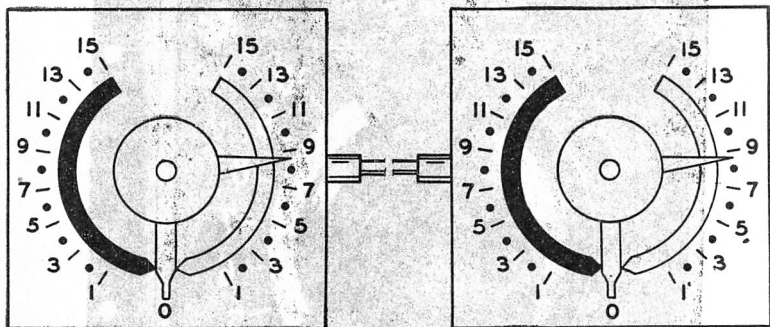


FIG. 7,882.—“Powerizer” fader for small theatres. *It is* of the potentiometer type with suitable resistance wire and resistance taps mounted on one unit, easily removable from the interior of the case. Connections are easily accessible and the entire unit may be wired in accordance with the Underwriters' Code. The entire unit is enclosed in a heavy steel case with two sets of markings, one in red, and one in white, to indicate its operation on either projector. The gain, per tap, is approximately in logarithmical increment.

Photo-electric Cell Amplifier.—The photo-electric cell circuit is inherently one of high impedance. In such a circuit local interference, or static, is readily picked up, and since the energy level is low, the current so acquired may be appreciable in comparison with the sound currents themselves. In addition the shunting effect of the capacity between the conductors is noticeable, particularly at the higher frequencies. Hence a vacuum tube amplifier, as shown in fig. 7,881, which serves both to increase the energy and to make that energy available across a low impedance circuit, is closely associated with the cell upon the projector itself.



FIGS. 7,883 and 7,884.—Fader showing master and auxiliary positions. Since in ordinary pictures, in order to run a continuous program, it is necessary to use two projectors alternately. As the picture from one machine is faded imperceptibly into that on the other so the sound record may be faded from one machine to the other without the audience being aware that a change has been made. At the end of each record or sound film the music overlaps the beginning of the next and a device called a fader is employed in making the transition. All that is necessary is to turn the fader knob when the incoming machine is started. This fader is in fact a double potentiometer. In the upper or normal operating range the change in volume in moving from one step to the next is hardly more than perceptible whereas in the lower range used only in fading the steps are large and the volume decreases to zero in one machine and builds up on the other very rapidly. By choosing the proper step in the upper range any volume of sound within reasonable limits can be obtained and the level obtained from different sound records equalized. The fader is ordinarily installed with one or more auxiliary dials and handles interconnected so that it may be operated from any projector position. In connection with the fader there is provided a switch for changing from the film to the disc input system and also a key for switching a spare projector in place of either of the regular machines.

The Fader.—As with ordinary motion pictures, two projectors must be used alternately to present a continuous program. At the end of a record, the music or speech coming from one machine must be blended imperceptibly into that from the other just as the picture from one reel is faded into that of the next.

At the end of each sound film or disc the music overlaps that at the beginning of the next; a device called a fader is used to make the transition.

By definition a fader is simply *a double potentiometer*.

As the starting projector goes into operation, the fader knob is turned and the current delivered to the amplifiers is changed quickly until it comes entirely from the new record. Ordinarily the fader is installed with auxiliary dials and handles, so that the operator can control it from any position around the projectors.

In its lower range, used in changing between projectors, the steps are rather large, whereas in the upper range the volume changes in scarcely perceptible steps. The fader thereby fills another use; it makes possible any volume of sound desired, within reasonable limits, by choice of the proper step in the upper range, and thereby permits equalizing the level of sound obtained from different records. There is provided as well a switch for changing from film to disc records, and the reverse, and a key for connecting a spare projector in place of either of the regular machines. Figs. 7,883 and 7,884 show a fader with master and auxiliary positions.

Main Amplifiers.—After passing through the fader, the sound currents go to the main amplifier, where their energy is raised to a level adequate for the loud speakers of the particular theatre.

A potentiometer is provided on the amplifier, but after it has once been adjusted at the time of installation it is ordinarily not changed; necessary adjustments in energy level are made on the fader instead.

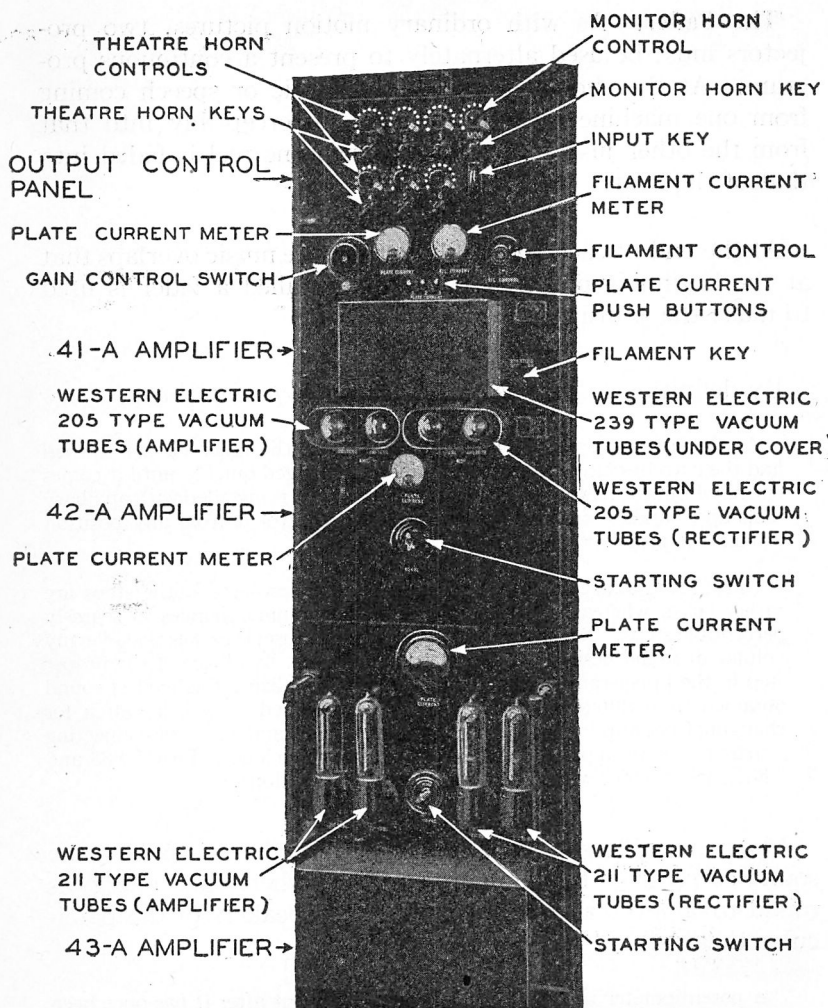


FIG. 7,885.—Typical amplifier panel. This combination is capable of an energy amplification of about 100,000,000 times and is so designed that all frequencies in the range from 40 to

Amplifier Panel.—Following the amplifier there is an output control panel consisting of an auto-transformer having a large number of taps which are multiplied to a number of dial switches. To the switches are connected the loud speaking receivers, so that the impedance of the amplifier output can be matched to the desired number of horns. Thereby is secured the most efficient use of the power available, and adjustment of the relative volumes of the individual horns is made possible at any time.

The Horns.—A theatre installation ordinarily contains four horns. They are mounted behind a transvocal screen, on which the pictures are shown, so that the sound may seem to come directly from the picture.

Two horns are mounted at the line of the stage and pointed upward toward the balconies and two are mounted at the upper edge of the screen, or above it, and directed downward. One or more Western Electric receivers are used with each of the horns.

A horn is ordinarily fitted with one receiver, but for outdoor use or other special requirements, it may be fitted with two, four or nine by a throat.

The maximum electrical input to a horn for continuous safe operation is approximately five watts per receiver. To disperse the sound waves over a large angle, more horns are needed than for a comparatively small angle.

FIG. 7,885.—Text continued.

10,000 cycles are amplified practically equally. A potentiometer is provided on the amplifier but while its handle is readily accessible it is ordinarily not used after having once been set at the time of installation to give proper results in the particular theatre. Necessary adjustments are made on the fader. The amplifier shown consists of three units. The first consists of three low power tubes in tandem, resistance coupled, and requiring a 12 volt battery delivering $\frac{1}{4}$ ampere to heat their filaments. The second consists of a single stage of two medium power tubes, connected in push pull arrangement with filaments heated by low voltage a.c. Two similar tubes in this unit operate as a full wave rectifier and supply rectified a.c. for the plate circuits of the amplifier tubes of both the first and second units. The third unit has a single stage of high power push pull amplifier tubes and push pull rectifier tubes and also operates entirely on a.c. These three types are capable of arrangement into combinations to meet the particular need. For small theatres only No. 1 and No. 2 are required. In the larger houses the high power unit No. 3 is added, while to meet exceptional conditions two or more of the high power amplifiers may be operated in parallel from the output of No. 2.

This directive characteristic of the horns is important, since it is responsible for the illusion that the sound comes directly from the mouth of the horn, that is, from the screen.

When the horn is replaced by a loud speaker of otherwise identical characteristics which radiates its sound over a very wide angle, the sound seems to come from a point some distance behind the screen, so that the illusion of coming from the picture is destroyed.

TEST QUESTIONS

1. *Describe a typical installation for reproducing sound pictures.*
2. *What is the construction of a disc record pick up?*
3. *Draw a diagram showing layout of a typical theatre for presenting sound pictures.*
4. *What is a photo-electric cell and how does it work?*
5. *Describe in detail the construction of photo-electric cells.*
6. *What is the construction of a photo-electric cell amplifier used at the projector?*
7. *What is a fader and how does it work?*
8. *Draw diagrams showing fader in master and auxiliary positions.*
9. *Where do the sound currents go after passing through the fader?*
10. *Describe the amplifier panel.*
11. *Draw diagrams illustrating recording and reproducing sound, showing intermediate processes.*
12. *How are the horns mounted?*

CHAPTER 197

Sound Apparatus Operation

As explained in the chapter on Synchronized Sound there are two general methods of recording sound:

1. Disc recording;
2. Sound on film.

In the sections following, a few operating hints will be given which will be found helpful for the projectionist in reproducing the recorded sound.

1.—Sound on Disc Operation

The revolving support upon which a sound disc is placed is called a *turntable*.

The following brief description of the Pacent disc system will show in general how disc systems work.

One motor drives both the projector and turntable through a gear box. A safety coupling between motor and gear box insures smooth and even running. Inside the gear box are gears that give the two drive shafts their proper speeds. The projector shaft terminates in a flexible coupling which takes care of possible misalignment developed during use. A pinion drives the projector head.

The turntable is driven from the gear box through a flexible coupling which eliminates possible vibrations reaching the tone arm. To further insulate the tone arm, it is mounted on a hub insulated by special cushions.

Pick up units are mounted in such a way that they can be easily replaced should trouble develop. To serve the operator a monitor speaker is mounted in the booth and the control of this speaker does not affect the volume or quality of the reproduction in the auditorium. It is up to the chief operator to decide whether he wants the speaker on or off.

The records used for this work are similar to standard phonograph records but larger and run at lower speed.

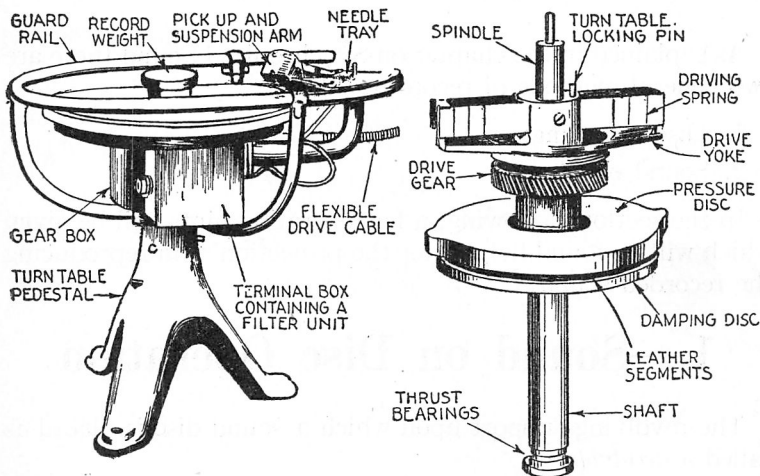


FIG. 7,886.—Typical synchronous turntable showing construction.

FIG. 7,887.—Viscous damping device of synchronous turntable. *In construction* a felt washer bears against one side of the fly wheel and introduces friction, or drag, and prevents any back lash in the gears, which might be caused by slight changes of motor speed, causing a *wow*. The pressure of the felt washer against the fly wheel can be adjusted by means of an adjusting screw, which is locked into position by means of a lock nut. The pressure on the washer should be adjusted to the lowest value that will just prevent *wows*.

The pick up needle travels from inside of records toward the periphery. An arrow indicates location of needle at start for proper synchronization.

The film is the same as standard film except that one frame is marked *start* and film number.

This frame is also marked with number O at the edge and every sixteenth frame is marked with the length in feet from the starting frame. The correct speed of the synchronized film is 90 ft. per minute and the equipment automatically regulates itself to have that speed constant during run. The projector machine and the turntable are mechanically connected so that no slipping which might result in improper synchronization is possible.

The general construction of a synchronous turntable is shown in fig. 7,886.

In order to avoid "wows" caused by sudden small variations in the speed

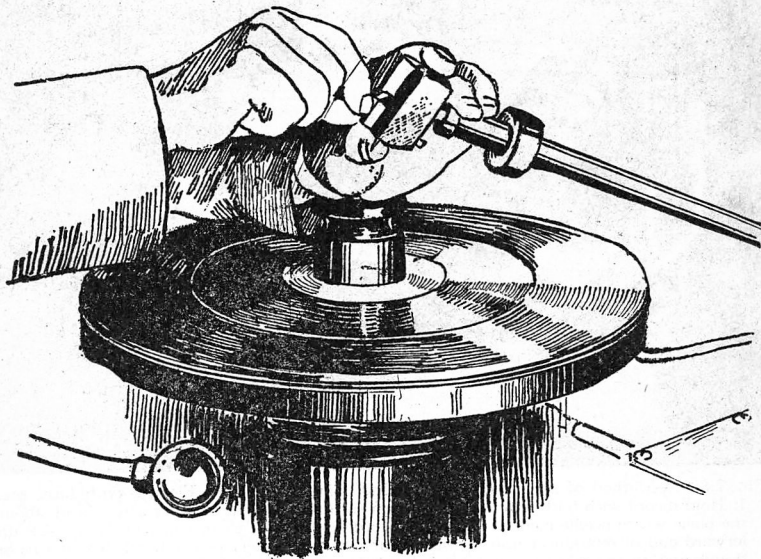


FIG. 7,888.—Patent disc reproducer showing method of inserting needle. If during a reel the sound suddenly die down, hold the pick up down in the groove, with the right hand and at the same time bear slight pressure on pick up head toward center of turntable. What happens when the sound dies down is that the armature inside of the pick up freezes against one pole piece. A light pressure will free the armature and the pick up will give good results again. Of course this pick up is only to be used during that reel and immediately after change-over replace pick up. To prevent this freezing happening, when inserting the needle always hold needle with thumb on needle point and apply a slight force to right side of pick up working from front of pick up then tighten up the turn screw and by holding of needle no force will be applied to armature during the tightening.

of the driving motor, a viscous damping device is incorporated in the turntable mechanism, as shown in fig. 7,887.

Synchronizing Sound on Disc.—To synchronize a sound disc with the picture requires that *the film and disc both start at definite reference points*. One frame of the film is always



FIG. 7,889.—Method of setting disc at starting point on Western Electric reproducer set.

1. Hold record with both hands and lay it on turntable so that starting arrow is at about the place where needle comes. Wipe off record lightly with cleaner provided; 2, pick up forward end of reproducer unit between thumb and forefinger of left hand so that tips of thumb and finger project about $\frac{1}{2}$ in. below bottom of unit; 3, move unit over until needle point is above starting groove and rest tips of thumb and forefinger on record surface so as to hold needle point just off record; 4, place right hand with fingers resting lightly on underside of turntable, near edge, and thumb on top of record, near edge, hold turntable steady and by moving thumb turn record so that starting arrow comes exactly below needle point; 5, lower needle down gently into starting groove at this point by slowly opening thumb and forefinger between which it is held. Do not push point into groove by sliding it sideways across uncut record surface, but lower it straight down. When it is in place rest fingers lightly on top of reproducer and gently press it toward each side to make sure needle point is in groove; 6, put record clamp over center pin of turntable and press it down in record firmly, but not too heavily.

marked in some way to indicate the frame which should be *in frame* when the film is threaded in the projector. After the film has been threaded as indicated, place the record on the turntable, and set record as explained in fig. 7,889. Motor must never be turned when adjusting record on turntable.

2.—Sound on Film Operation

In reproducing sound on film there are a few requirements of primary importance:

1. The light which shines through the film must be steady.
2. The beam of light must be as thin as the beam used in recording, and exactly as wide as the sound track.
3. The speed of the film passing the light beam must be the same as the film speed of recording and *must be constant*.

Variations in speed would cause variations of pitch which would be recognized as "wows."

4. The sound track of the film must be clean.

A dirty sound track would cause extraneous variations of the transmitted light and produce a grating noise in the loud speakers.

Variable Density and Variable Area Reproduction.—Although the sound tracks of the variable area and variable density recordings do not look alike, *the variations of the light transmitted through them are the same*. Therefore, reproducing equipment which is suitable for reproducing from one type of recording is equally capable of reproducing from the other.

All producers of standard sound recordings on film use the same width of sound track, and use a light beam of approximately the same thickness.

Sound Head.—The apparatus through which the film travels

to produce the sound is called a sound head. In general, it consists of a housing containing:

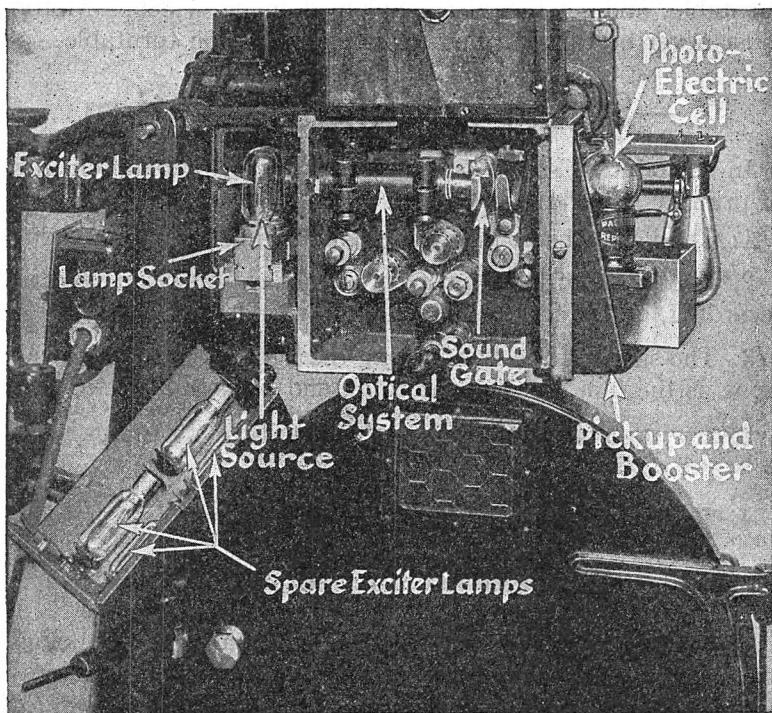


FIG. 7,890.—Patent sound head showing light source, optical system and pick up system.

The filter system consists of two fly wheel members, spring driven from the same shaft but through a gear system of a slightly different ratio for each fly wheel. As a result, these fly wheels, during the operation of the machine, revolve at a slightly different rate of speed though the relative speed is low, normally. These wheels are placed fairly close together in line with the axis of each and there is inserted between them, at right angles to the axis, a leather washer which contacts the sides of both wheels and in that way forms a frictional contact. To one of the fly wheels is connected the constant speed sprocket, the other is used as an impulse filter. In its operation, any variation in the speed of the fly wheel to which is connected the constant speed sprocket will change the relative speed between both wheels and will bring about a corresponding change in friction.

1. An exciter lamp assembly.

In separate compartment.

2. An optical system.

For focusing the light on the film.

3. A sound gate.

For guiding the film past the beam of light.

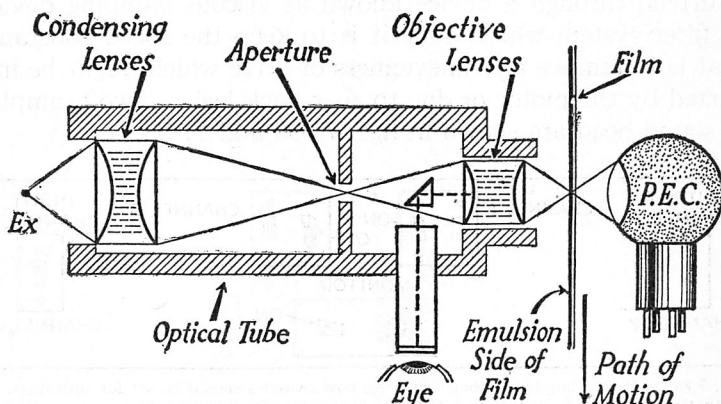


FIG. 7,891.—Diagram of the light source, optical system and pick up system in the Pacent sound head. Ex is the light source or exciter lamp. The optical system immediately at the right comprises a series of suitable lenses encased in a lens barrel or optical tube, and, following this, is the sound gate (not shown) over which the film rides before contact with the constant speed sprocket. *In operation* the light, modulated by the impressions on the film, falls upon the window of the sensitive photo-electric cell. This light sensitive cell, converts the varying intensity of the light beam into electrical impulses which are amplified by the booster, voltage amplifier, power amplifier and thence to the loud speakers.

4. A viscous damping device.

To insure constant speed of the film.

5. A photo-electric cell and its transformer.

For translating the light variations into electrical variations.

A typical sound head is shown in fig. 7,890 and the manner in which it works in fig. 7,891.

Viscous Damping Device or Filter System.—The importance of having the film move at a constant rate of speed when passing the sound gate is well known, and need not be discussed further here. The sprocket which pulls the film through the sound gate is called the *constant speed sprocket* because it is driven through a device known as viscous damping device or filter system whose duty it is to keep the speed constant, that is to remove any unevenness of drive which might be imparted by the motor or due to gear back lash. Two examples of sound head are shown in figs. 7,890 and 7,893.

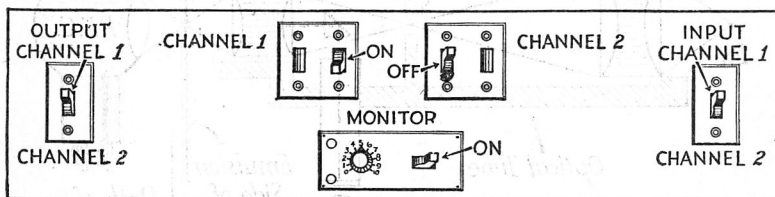


FIG. 7,892.—Pacent amplifier cabinet showing how switches should be set for operation. **In starting:** 1, set the fader at zero. 2, throw on main switch for channel one on amplifier cabinet; throw on input and output switches for channel one on same cabinet; throw on exciter lamp switch; throw on filament supply switch for booster unit; throw on speaker field switch—if current supply be other than 50 or 60 cycles a.c., throw on switch for power supply unit for amplifier and power pack.

Threading the Film.—To set up a sound film ready for operation the following instructions will be found useful.

1. See that the fader is at zero and that film pick up circuits are connected to it.
2. On projector head, place aperture sound track mask in position.
3. On projector, place framing lever in central position.

Move projector mechanism by turning the hand wheel so that shutter cut off blade is uppermost, lens is open and intermittent has just ceased moving. Thread projector mechanism with film in usual manner except as follows:

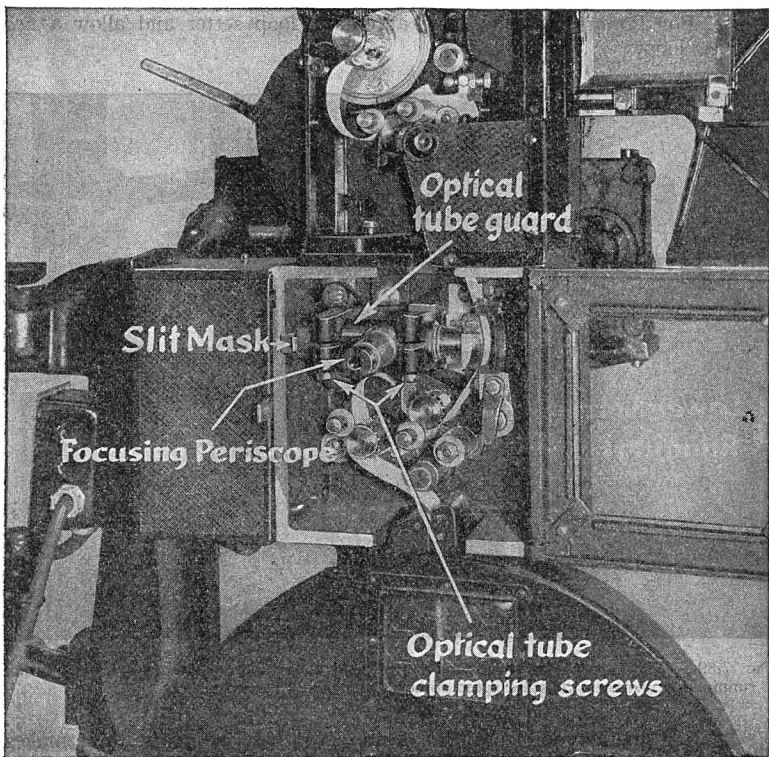


FIG. 7,893—Patent sound head showing threading of film. Note periscope in position for focusing test. After threading the film through the projector head in the ordinary manner it should be lead through the outlet in the lower part of the projector head into the opening in the upper part of the sound head thence over sound gate and around constant speed sprocket and over take up sprocket to rewind magazine. Film should be made taut between take up sprocket in projector head over sound gate and around constant speed sprocket, then released one hole. Caution is advised at this point to make sure that the lower normal running loop as shown in fig. 7,894 is large enough to prevent breaking film.

a. For Simplex, be sure that loop between intermittent sprocket and lower sprocket of head, is such that film just comes in line with edge of head, as shown in fig. 7,895.

b. For Motiograph, allow a tight *two finger* loop between intermittent sprocket and lower sprocket of head.

c. For Powers, thread above automatic loop setter and allow a *two finger* loop.

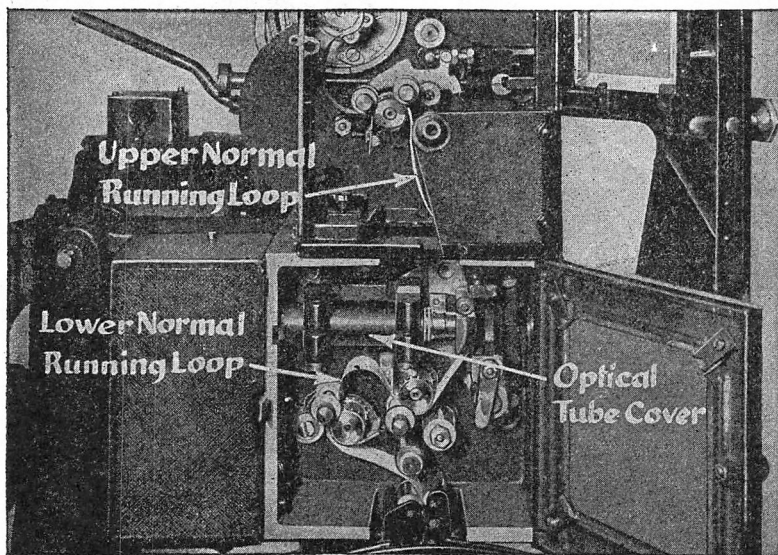


FIG. 7,894.—Patent projector head and sound head showing proper size for lower normal running loop between constant speed sprocket and take up sprocket.

d. If using a type of projector head other than one of the three makes just mentioned, allow a length of film equal to $19\frac{1}{3}$ frames, or $14\frac{1}{2}$ " between center of picture aperture in the projector head, and center of light gate aperture in the reproducing machine. In other words, if the frame centered at projector aperture be called No. 1, then, counting downward along film, middle of light gate aperture should be $\frac{1}{3}$ of a frame past center of No. 20. This gives perfect synchronism between sound and picture with all makes of heads, and is basis of rules for threading just given.

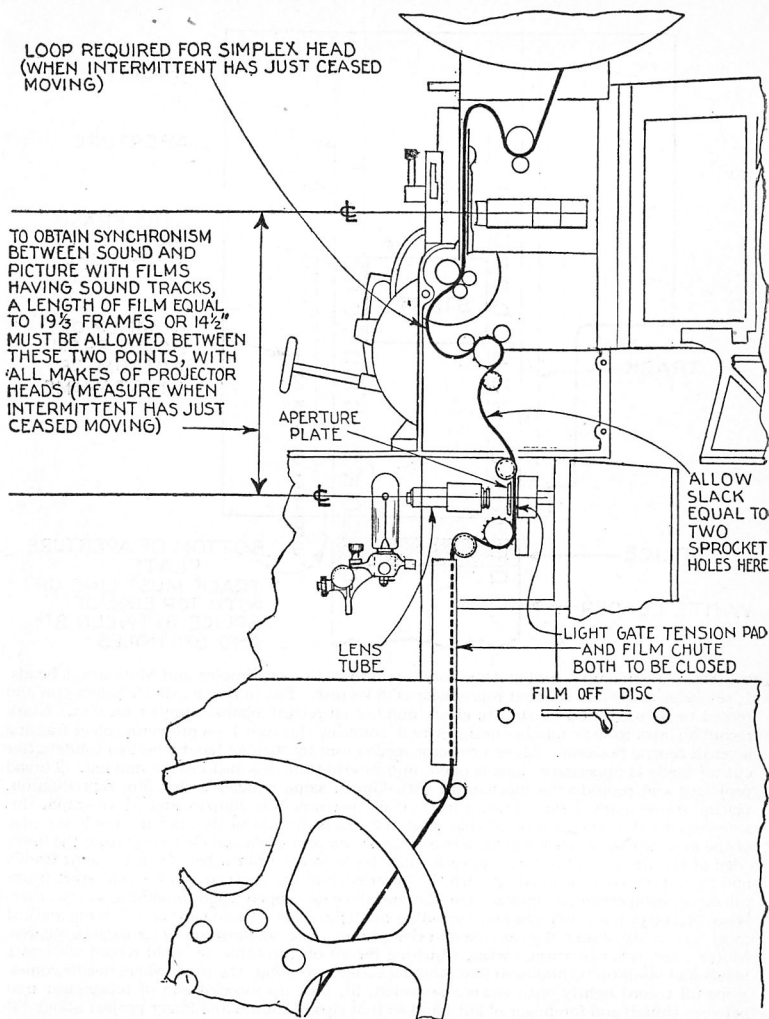


FIG. 7,895.—Threading projector and Western Electric reproducer set (sound head) for film reproduction.

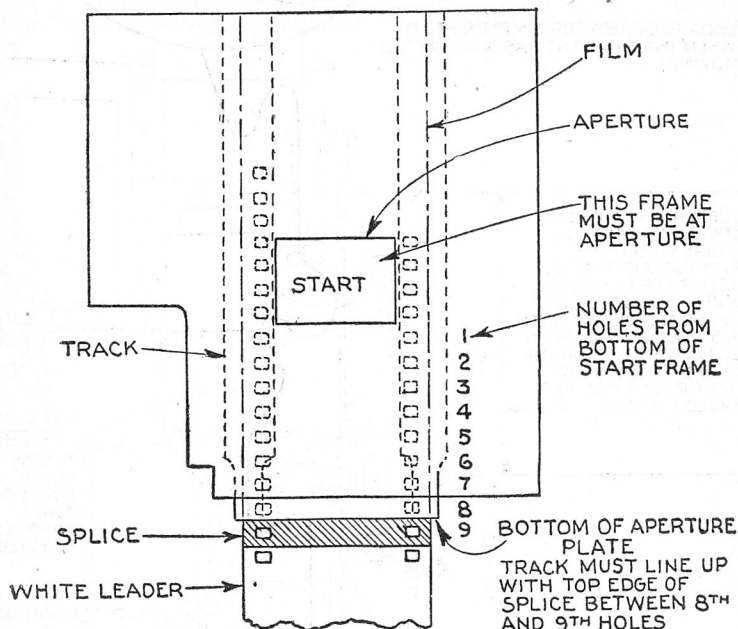


FIG. 7,896.—Setting up record and film for disc reproduction on Simplex and Motiograph heads.

1, set fader at zero; 2, see that reproducer is in its rest. Put in new needle; 3, select film and record to be used, and be sure to check number on record against number on film. Mark record on label to show number of times used, counting this run; 4, on projector, place framing lever in central position. Move projector mechanism by turning hand wheel so that shutter cut off blade is uppermost, lens is open, and intermittent has just ceased moving. Thread projector and reproducing mechanism with film in same manner as for film reproduction, placing frame marked *start* directly in front of aperture. On Simplex and Motiograph, this step is easier if it be remembered that when a frame is in front of the aperture the lower edge of the aperture plate track will be between the *eighth* and *ninth* sprocket holes from the lower edge of the frame. Therefore, splice a white leader on the *ninth* hole from the *start* frame, and then when splice is lined up with the lower edge of the aperture plate track, *start* frame will be at the aperture, as shown. On Powers, the gate is open when threading, so that there is no difficulty; 5, set up record on turntable as in fig. 7,889. In doing this, following method must be strictly observed so as to avoid risk of imperfect synchronism or damage to records. Motor must never be turned when adjusting record on turntable; 5^a, hold record with both hands and lay it on turntable so that starting arrow is at about the place where needle comes. Wipe off record lightly with cleaner provided; 5^b, pick up forward end of reproducer unit between thumb and forefinger of left hand so that tips of thumb and finger project about $\frac{1}{2}$ " below bottom of unit; 5^c, move unit over until needle point is above starting groove and rest tips of thumb and forefinger on record surface so as to hold needle point just off record; 5^d, place right hand with fingers resting lightly on underside of turntable, near edge, and

4. Thread film through film reproducing mechanism exactly as shown in fig. 7,895.

In doing this, allow for *slack*, between lower sprocket of projector head and sprocket of film reproducing mechanism, a length of film equal to *approximately two sprocket tooth intervals*.

5. After film has been properly located on reproducing machine sprocket, do not forget to *release tension pad*, so that it bears on film and holds it close up against aperture plate in front of lens tube, as shown in fig. 7,895.

Door cannot be shut unless tension pad is released. Also close the film chute cover so as to have the film completely enclosed in case of fire.

6. On synchronized feature pictures, by starting and stopping motor with starting switch run off as much film as necessary to bring end of "Part No" leader approximately up to projector aperture. Avoid doing this to excess, as it tends to burn up the switch contacts.

Splicing Film for Disc Reproduction.—Vitaphone film has 16 frames per foot, and each foot is numbered. Beginning with O, at the starting mark, the 16th frame after the starting mark is marked No. 1. The 16th frame after No. 1 is marked No. 2, and so on throughout the print. There are, therefore, 15 frames without numbers between each pair of numbers.

FIG. 7,896.—Text continued.

thumb on top of record, near edge, hold turntable steady and by moving thumb turn record so that starting arrow comes exactly below needle point; 5^c, lower needle down gently into starting groove at this point by slowly opening thumb and forefinger between which it is held. Do not push point into groove by sliding it sideways across uncut record surface, but lower it straight down. When it is in place rest fingers lightly on top of reproducer and gently press it toward each side to make sure needle point is in groove; 5^f, put record clamp over center pin of turntable and press it down on record firmly, but not too heavily; 6, turn over mechanism by hand wheel until turntable and record have revolved about half a turn. See that needle tracks properly on record and film travels free; 7, on synchronized feature pictures, by starting and stopping motor with starting switch run off as much film as necessary to bring end of *part No.* leader approximately up to projector aperture. Avoid doing this to excess, as it tends to burn up the switch contacts.

By this system, the position of every single frame in the reel is indicated.

In synchronized features there are in addition other numbers on the margin of the film which indicate the scene numbers of the picture.

These numbers can be distinguished from the footage numbers, because they have a dash at each side, as for instance -286-, the footage numbers themselves being simply 286, without the dash at either end.

In cases where the scene and footage numbers conflict, the footage number is omitted, but is counted, and reference will have to be made to the next footage number in sequence.

If a footage number do not appear at each 16th frame, continue counting until the next number is reached, when there should be 31 frames between the two footage numbers.

With the numbering system described, it is easy to ascertain whether or not a print has the proper number of frames, by examining each splice and counting the footage numbers on each side. The two numbers should be consecutive and there should be 15 frames without numbers between them.

In case of a break in a film, make a patch by inserting black leader.

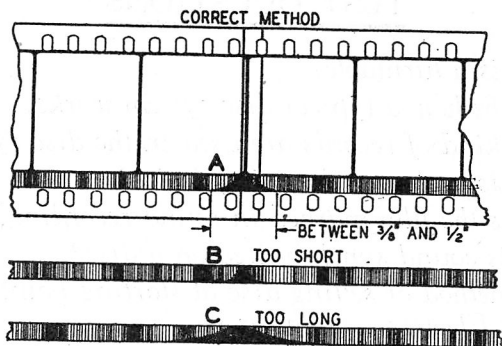
Be sure that the number of frames of black leader inserted is exactly the same as the number of frames taken out of the film, plus the frames used for the patches. After putting in the black leader, be sure to check up and see that the numbers follow in sequence and that there are exactly 15 frames without numbers between each pair of footage numbers.

If any numbered frames be missing, or if the missing portion be more than one foot, both sides of the break to the next number will have to be checked, and after making the splice, do not forget the intervening numbered frames.

Splicing Film for Film Reproduction.—In case film carrying a sound track become broken, cut out as few frames as possible when making the splice. A break in the sound track is usually even more noticeable to the audience than a break in the picture. However, do not go to the extreme of saving weak film that will cause trouble later.

A plain splice, no matter how carefully made, will cause a click to be heard from the sound projectors as it passes through the film reproducing attachment, because the two edges and the overlap disturb the uniformity of the sound track and produce the same effect as though noises had actually been recorded on the track.

In dealing with film of this type, therefore, first make a splice in the usual manner and then paint over this splice in black, as shown at A, in figs. 7,897 to 7,899.



FIGS. 7,897 to 7,899.—Method of splicing film with film track.

The painted mark on the sound track should be roughly triangular in shape with a blunted apex and between $\frac{3}{8}$ inch and $\frac{1}{2}$ inch wide at the base.

If the splice be painted in this manner, it will be almost inaudible when passing through the reproducing attachment, as the change in the light intensity which it causes will be at a frequency below the audible range.

If the mark be made too short, as shown at B, the click will be very pronounced; if it be made too long, as at C, there will not be a click but there will be a noticeable pause in the sound owing to so much of the sound track being obliterated.

For opaquing splices, the use of Zapon concentrated black lacquer No. 2002-2 is recommended. It is made by the Zapon Company, Stamford,

Conn. When a thinner is necessary, Zapon thinner No. 20 is recommended. The lacquer should be applied to the shiny or celluloid side of the film and not to the emulsion side. It dries almost instantly, adheres tightly, and is much more satisfactory than India ink or other substances. If for any reason it should become necessary to remove it, a rag soaked in lacquer thinner will be effective.

Splices in the negative in making up subjects sent out by the producers are taken care of in the printing and may be observed by the triangular marks along the sound track near changes of scene.

TEST QUESTIONS

1. *What is a turntable?*
2. *Describe how a typical disc system works.*
3. *What kind of records are used in the disc system?*
4. *What is a viscous damping device?*
5. *How is the film marked in sound recording?*
6. *How is sound synchronized on a disc?*
7. *Give method of setting disc at starting point on Western Electric reproducer set.*
8. *What are the requirements for reproducing sound on film?*
9. *Is reproducing equipment suitable for reproducing from both variable density and variable area sound tracks?*
10. *Of what does a sound head consist?*
11. *How does a sound head operate?*
12. *Describe the operation of a viscous damping device or filter system.*
13. *Explain in full the method of threading sound film.*
14. *Describe the splicing of film for disc reproduction.*
15. *Describe the splicing of film for film reproduction.*

CHAPTER 198

Sound Picture Speed Control

In all types of projectors equipped with sound heads or reproducers, there are two essential requirements.

1. The sound must be in synchronism with the film.
2. The apparatus must be run at a pre-determined constant speed.

The first requirement needs no explanation.

In regard to the second requirement it should be noted that musical pitch varies directly with frequency or rate of vibration.

The faster the record is rotated, or sound track is run, the higher the pitch of the sound given out.

In order, therefore, that the reproduced music may be of the same pitch as that recorded, *the record must run at an assigned speed*, and to keep the pitch from varying during the playing of the record, this speed must be prevented changing. To attain these ends, the speed of the driving motor must be accurately controlled.

A good musical ear will detect sudden changes in pitch produced by a change in speed of only one half of one per cent.

To make sure, therefore, that a discernible change in pitch never arises, speed regulation better than one half of one per cent is required at all times. As further allowances seemed desirable to provide a suitable factor of safety, a regulation of two tenths of one per cent was agreed upon.

The interlocking of the motor system employs a principle known for many years in the electrical power field. It consists of *connecting the stators and wire wound rotors of polyphase slip ring induction motors with similar electrical impedance characteristics, in parallel, and the placing of an alternating voltage across the stator.* Each motor acts as a transformer.

The rotors of all driving motors are brought into the same electrical

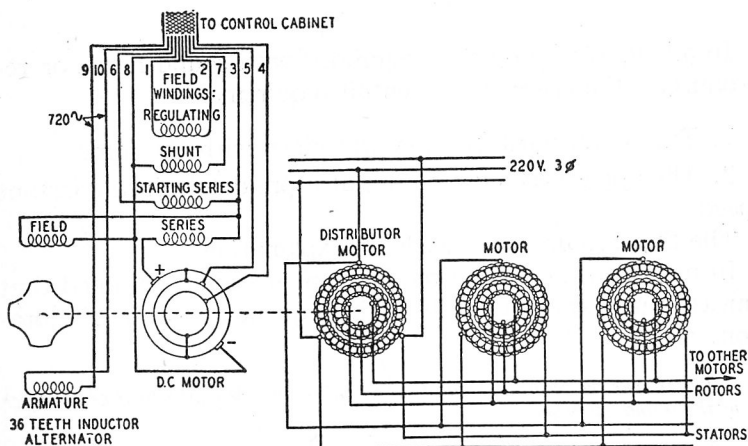


FIG. 7,900.—Diagram of motor system.

phase relation as is presented by the distributor motor. This system gives a strong interlocking action between all motors.

Mechanical rotation of the distributor rotor produces a corresponding rotation of all other interlocked rotors. Hence, if the rotor on the distributor be driven at a constant speed, all interlocked motors are likewise driven at the same speed independently of the power supply frequency and the actual number of revolutions from start to stop is exactly the same for all motors.

The system may be thought of as a long shaft as in fig. 7,901, with all loads geared directly thereto. The shaft is then driven by the distributor

motor at a constant speed and all loads will then run in synchronism and likewise have the same number of revolutions from start to finish.

This feature of having the same number of revolutions from start is an important one. It permits the marking for synchronization of the sound film and picture film while stationary, while still having complete synchronization throughout, and is also important in the transferring of the sound record from one film or disc record to another film or disc in a dubbing process.

In the sound picture system a few comparatively simple electric circuits *act as a governor to correct the slightest change in speed of the driving motor.*

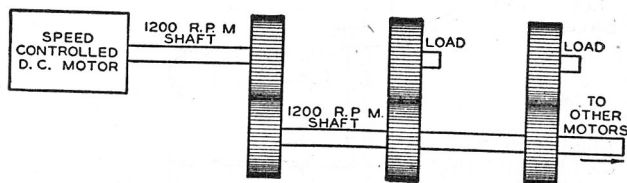


Fig. 7,901.—Mechanical analogy of motor system.

To make clear the principles involved, the electrical governing apparatus may be compared to the familiar steam engine governor shown in fig. 7,902. In this comparison the electrical governing apparatus may be split up into three parts corresponding to those of the fly ball governor. One part will substitute for the driving link (not shown in fig. 7,902) between the engine and the governor spindle, another for the fly balls themselves and their connecting levers, and a third for the steam valve that changes the torque of the engine.

The driving link for the electrical system is a 720 cycle alternator coupled to the main driving motor of the projector unit.

The governing circuit proper is a special bridge circuit shown in fig. 7,903.

One arm of the bridge has a fixed inductance and condenser in series, which are adjusted to tune the circuit to 720 cycles. At this frequency the impedance of this arm is a resistance only and the impedance of the

arm D; is made a resistance of the same value. At 720 cycles the ratio of these two arms, therefore, is unity, as is that of the other two arms, made up of the primary of a transformer divided at its half tap. The small alternator, connected across the transformer, thus becomes the source of power for the bridge. This arrangement makes an extremely sensitive analogy to the fly ball governor and lever system. The voltage

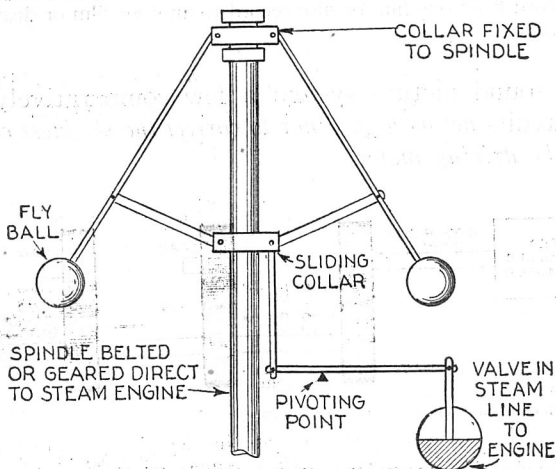


FIG. 7,902.—Familiar fly ball steam engine governor showing how sensitivity may be changed by moving the pivoting point to the left or right.

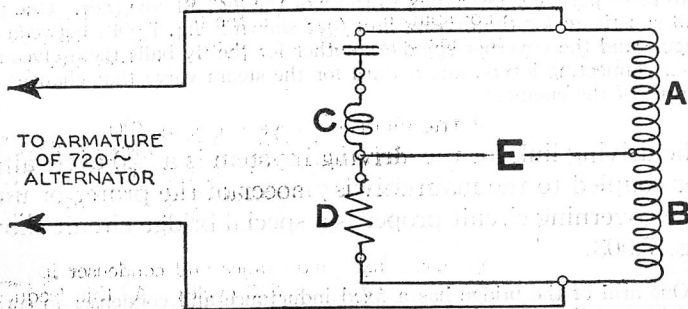


FIG. 7,903.—Sound picture governing circuit proper. Voltage E, shifts 180° in phase as the speed changes from any value below 1,200 r.p.m. to any value above it.

E, from the mid point of the coils A, and B, to the junction of arms C and D, which is zero at 720 cycles, shifts its phase 180° as the speed changes from any frequency below 720 cycles to any above it. Below 720 cycles the current in C, is leading due to the predominance of the condenser and above 720 it is lagging due to the predominance of the inductance. Instead, therefore, of a gradual change as the speed changes from its desired value there is an abrupt one which furnishes a basis for accurate speed control.

Acting as the steam valve to control the speed of the motor is an impedance coil with three legs, as shown in fig. 7,905.

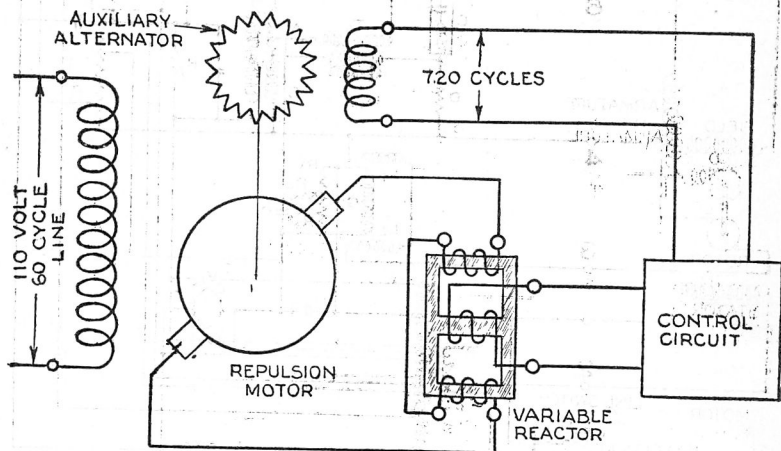


FIG. 7,904.—Torque control for driving motor. This is obtained by a three legged inductance coil, the impedance of which is changed by direct current flowing around the middle leg.

The two outer legs L_1 and L_2 , are connected to the motor armature and serve as the impedance controlling the speed.

The middle leg G, carries a direct current winding. As the current in this winding increases the magnetic flux in the two outer branches increases to saturation and their impedance decreases. The torque of the motor varies inversely with the reactance of the coils, L_1 and L_2 , and as a result the greater the direct current flowing into the coil G, the higher will be the torque of the motor.

The link between the bridge and the three legged inductance is a vacuum tube circuit.

This circuit causes more direct current to flow as the motor speed tends to fall. This complete circuit, shown in fig. 7,905, includes the detector tube V_4 , and two tubes V_1 and V_2 , which supply current for the middle winding of the impedance coil. Tube V_3 is a rectifier to supply excitation for the 720 cycle alternator and grid biasing voltage for V_1 , V_2 and V_4 .

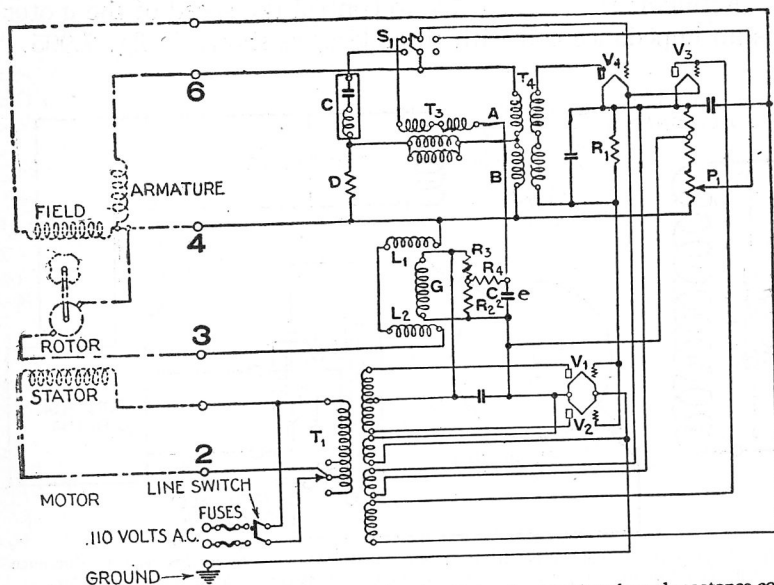


FIG. 7,905.—Complete diagram of the governing circuit showing the three legged reactance coil in the center. Switch S_1 is normally thrown to the left.

Plate voltage for V_4 comes from the alternator through the transformer T_4 , and its phase is fixed. Grid voltage for this tube is from the bridge output circuit E, the phase of which shifts 180° as the alternator speed changes from below to above 1200 r.p.m. This 180° shift of phase changes the voltage of the grid relative to the plate from negative to positive or vice versa, and thereby causes a relatively large change in the plate current, which, flowing through R_1 , causes a correspondingly large change in the

grid voltage of tubes V_1 and V_2 , and thus in the direct current to the impedance coil.

The bridge circuit makes a very sensitive governing device, but with it alone some permanent change in speed would be required to compensate for each change in load or line voltage. Something else must be added if the speed is to be constant for all conditions. Also some dashpot equivalent must be used to prevent the speed oscillations mentioned.

These two functions are accomplished by a network composed of R_2 , R_3 , R_4 and C_2 , properly connected to the other circuits. Current flowing in the plate circuit of V_1 and V_2 , to the coil of G , flows also through R_2 and R_3 . The drop across C_2 which after a short preliminary period is the same as that through R_2 , feeds back a voltage to the grid circuit of V_1 , and thereby causes the additional regulation required. To slow down the action of this feed back, however, R_4 in series with C_2 , is connected in parallel with R_2 as shown.

The feed back voltage is that across C_2 , and this rises or falls slowly as the condenser must be charged or discharged through the high resistance R_4 .

By these means, in the comparatively simple and compact electrical circuit shown in fig. 7,904, a governor is provided, similar in its functioning to the fly ball governor of fig. 7,902, that will control the speed of the driving motor under all ordinary conditions to within the required two-tenths per cent.

The switch S_1 , was added to the circuit so that, when the picture projection machine was used for ordinary silent motion pictures, when such close speed regulation is not required, it could be thrown to the right and hand regulation obtained by the potentiometer P_1 . This is needed to vary operating speed of the projector to meet a definite time schedule for showing the picture. When the schedule permits, however, accurate speed regulation is preferred since it enables a leader to keep his orchestra in better step with the picture.

TEST QUESTIONS

1. *What are the two essential requirements of projectors equipped with sound heads?*

2. Why must a disc run at a pre-determined constant speed?
3. What principle is employed in the interlocking of the motor system?
4. Describe in full detail the method of obtaining constant speed.
5. Give a complete diagram of governor circuit.

CHAPTER 199

How to Run the Show

Preliminary Considerations.—Before giving in detail the steps to be followed in running the show, some general points will be touched on. Before any public showing, all presentations should be rehearsed as covered in the section on Rehearsing.

The fader must always be kept at zero when the house is empty, except when testing with all theatre horns turned off, or when voice or music is actually being reproduced, with the motor up to speed, as covered in detail in these instructions. This is necessary:

1. To avoid the record surface noise or film noise being noticed.
2. To prevent the possibility of noises being heard from the horns at times when the pick up equipment is being handled.
3. To preclude the voice or music being heard in distorted form when the motor is speeding up or slowing down, in case it has to be stopped during a reel from film breakage or other cause.
4. When making a change over as described in detail in the instructions which follow, move the fader as smoothly as possible, and if a complete change over cannot be made in one movement, stop at zero for a fresh grip. Be careful not to over shoot the setting and then have to come back to it.

If the installation include disc pick up, always keep the re-producer in the rest except when a record is set up.

Under no circumstances is it permissible to run pictures with synchronized voice or music at any other speed than 90 ft. per minute.

When running such pictures the motor control box regulating switch must *always* be set at "Reg" and *never* at "Var." Any adjustment in the

timing of the program by speeding up numbers or slowing them down must therefore be done elsewhere than in the synchronized reels.

A member of the staff appointed by the manager should remain in the theatre all through the performance so that the operator may have immediate and proper notification in case any part of the show is not coming over as it should.

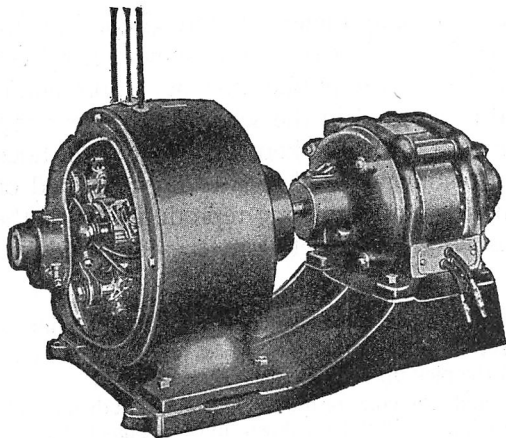


FIG. 7,906.—General Electric *a.c. to d.c. motor dynamo compensarc*. For use when the source of power is *a.c.* The equipment operates from an *a.c.* circuit and delivers *d.c.* of proper voltage to the projection arc. Sixty per cent of the moving picture theatres are located so that only *a.c.* is obtainable. The motor in this set, being a standard induction motor, can be obtained for any commercial lighting or power circuit whether single, two or three phase.

The observer should be competent to judge quality of reproduction, synchronism, etc. He should be within reach of the observer's telephone and given responsibility of notifying the operator immediately anything goes wrong. He should also keep the operator informed as to how well the house is filled, so that the latter can adjust the volume if necessary.

Never make the monitor horn so loud that it can be heard outside the projection room.

Keep the volume up just enough to follow the sound after the numbers have started, and make it a little louder before cues.

Do not cut synchronized film or sound film except in case of breakage.

If it be found desirable to eliminate bows at the end of the film, use the douser. If there be insufficient leader to permit proper threading of the film at starting, more blank leader may be added, provided of course, it is added *before* the "start" mark. Leader must always be so added if it be found that the voice or music begins before the motor is fully up to speed.

If the machine be equipped with a safety device which stops the motor when the film has run through, then, with disc reproduction, in case the record do not end until some time after the finish of the film, this ending will be spoiled through the safety device shutting down the equipment, unless sufficient blank film be added at the end to prevent this device operating until the music is finished.

Check this point during rehearsal and before running show make sure these blank lengths have been added to any reels that require them.

With subjects using disc reproduction a broken film is a more serious interruption than with ordinary subjects, on account of the need for synchronism between record and film, and with film reproduction, a break is also specially objectionable because it cuts off the music as well as the picture. Therefore, examine all synchronized films and sound films with extra care while re-winding, so as to catch tears before they develop into breaks. For this reason, rewind by hand and not by motor.

In film reproduction make especially sure that the film has been put in as good condition as possible and that the mechanism is clean. Oil or grease from the projector or film pick up mechanism is particularly liable to get on the first few feet of film. Keep emergency films in containers unless they have to be used.

Synchronized films and sound films come treated ready for immediate use, and require no different care from ordinary films, except as just noted.

Keep all records in envelopes they come in, when not in use. Put each record in its envelope with the playing side next the felt, and facing you. Keep the records in correct order for the next show.

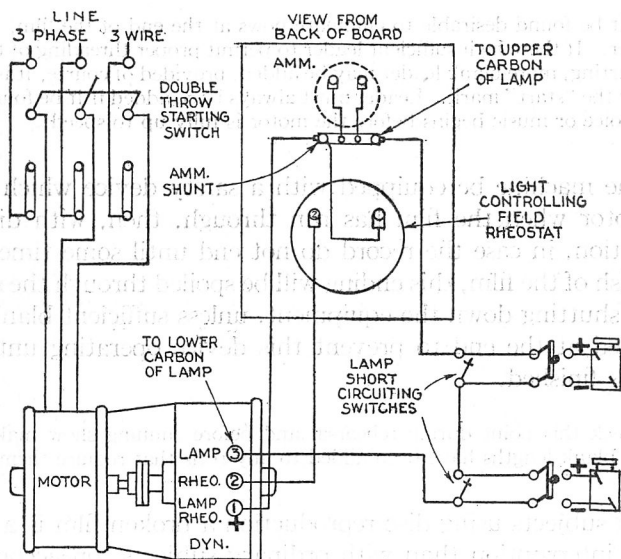
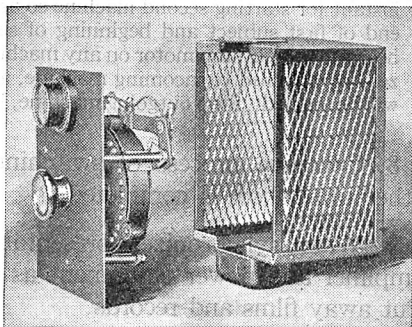
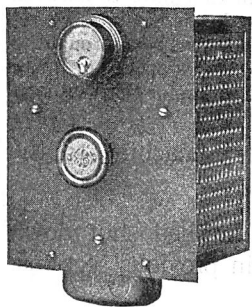


FIG. 7,907.—General Electric motor dynamo compensarc wiring diagram. *In operation* the current can be varied over a wide range by means of the field rheostat as the operator sees fit. The first arc is struck in the usual manner. The second lamp being short circuited by means of the switch. When ready to change over to the second lamp the carbons are brought together until they touch. The short circuiting switch is then opened. To shut off the first lamp the carbons are gradually brought together and the short circuiting switch closed. Two picture machines and a spotlight can be used, if only two of the arcs be used at the same time for change over and only one burn continuously. Since no steady resistance is used the dynamo has been designed to operate over a wide range of load with approximately the same operating efficiency, whether one or two of the lamps be burning.

Synchronized Subjects.—The process of running synchronized subjects, using either film or disc reproduction is as follows:

1. Follow out starting and testing procedure, and set up first two synchronized numbers on the two machines to be used, exactly as described in preceding sections.

2. Strike arc on first projector in usual manner.
3. When lamp is in operating condition and show is ready to proceed, start motor of first projector.
4. When motor is up to speed open douser.
5. Bring fader up slowly so that it reaches correct setting just before voice or music begins. This needs rehearsal.



FIGS. 7,908 to 7,910.—General Electric control panel with ammeter and field rheostat for motor dynamo *compensarc*.

The motor used in the Western Electric equipment takes four or five seconds to speed up, because of heavy fly wheel required. Never move fader from zero before motor has reached full speed, as this will completely spoil beginning of speech or music. If sound begin before motor has finished speeding up, add leader to film as required.

6. For synchronized feature pictures, keep track of operation by listening to monitor and by watching screen for cues.

Do not make monitor so loud it can be heard outside projection room. At cue SM, as given on cue sheet, start motor on second machine. At cue CO, operate change over so as to switch picture from outgoing projector to incoming. As soon as voice or music from outgoing machine is finished, bring

fader of this machine to zero, and then up to proper setting for incoming machine in time to catch first note of music. This needs rehearsal. Stop outgoing machine, kill arc and set up third film and also third record, with disc method.

7. For synchronized subjects other than feature pictures, keep track of operation by listening to monitor and watching pictures.

As soon as last note of music or last word is heard, bring fader to zero, then fade out picture as soon as subject matter requires. Start second machine in same manner as already described for first machine. Proper instant for starting second machine so as to get right time interval between end of first subject and beginning of second, must be determined by rehearsal. Never stop motor on any machine before fader has been brought to zero or switched to incoming machine, as otherwise end of speech or music will be spoiled. Stop outgoing machine, kill arc, and set up for third subject.

8. Continue process of switching from one machine to the other until show is completed.

9. When synchronized presentations are finished shut down amplifier and power equipment as covered in previous sections. Put away films and records.

10. When using film pick up, after running each reel, wipe off with a rag the light aperture and film tracks of aperture plate and tension pad in reproducing attachment, so as to guard against possibility of dirt accumulating and obstructing light beam or scratching film.

Non-synchronized Subjects.—When films without synchronized accompaniment are being used, and it is not desired to operate at the standard synchronized speed of 90 ft. per minute, throw the regulating switch on the motor control box to the VAR, position and turn the control knob to regulate the speed as desired. The motor is started and stopped by the foot switch used in synchronized operation.

Use of Tilting Mechanism.—If the house have both a front and a back screen, change the projection angle, in going from one screen to the other, by turning the tilting hand wheel.

Upper and lower stop nuts are provided to check the movement of the hand wheel when the correct angle is reached. Be sure to loosen the tilting clamp before turning the hand wheel, and also to tighten it again when the angle has been changed.

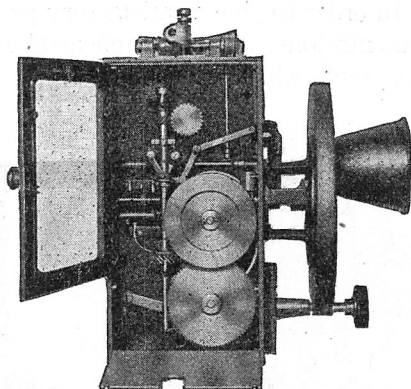


FIG. 7,911.—Superior projector. Head mechanism, gear side showing new rear shutter, new framing device and special gear for attaching sound reproducer equipment. *Timing Shutter*; since the shutter must operate in exact synchronism with the intermittent movement it is necessary that they should be in proper relation. To accomplish this turn the fly wheel in the direction it revolves until the intermittent sprocket starts to move, after which set the lower edge of the larger wing of shutter about one eighth of an inch above centre of the aperture plate opening. If travel ghost, streaks or a blurry effect be apparent the shutter is out of time and should be adjusted until these conditions are eliminated.

If for any reason it be desired to change the tilt of the machine by a large amount, first see that the tilting clamp is tight, then loosen the two tilting stud set-screws, which grip the tilting rod. Hold the rear of the lamp house bracket in one hand, loosen the tilting clamp with the other, and tilt the machine as desired. Then tighten clamp and set-screws. See instructions on page 4,841.

Use of Foot Brake.—When the foot switch is pressed down lightly, it turns off the starting switch and stops the machine.

If it be pressed down more heavily, against the resistance of the spring, it applies a brake to the motor fly wheel. However, *this braking feature is not to be used as a regular practice*, as this is not necessary and would cause excessive wear. *It is only to be used in emergencies*, such as film breakage, when a quick stop is necessary to avoid damage.

Rehearsing.—In order to give a satisfactory performance with synchronized presentations, adequate rehearsal is necessary to cover the various points which will be listed.

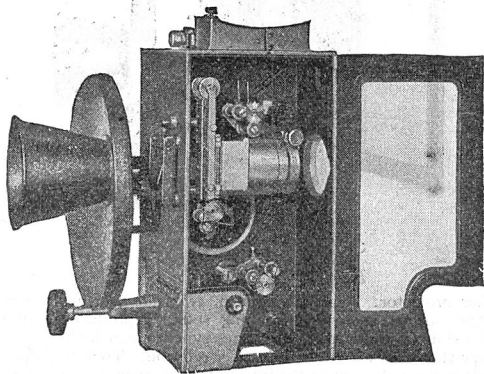


FIG. 7,912.—Superior projector. Head mechanism, film side showing new rear shutter, new framing device, mask on aperture to cut off sound track in connection with sound film.

The house manager should be present at these rehearsals with an observer at the telephone set. The subjects should be run off in the same way as for an actual performance. Time spent in careful rehearsing will be amply repaid in the perfection of the show, and the actual presence and interest of the house manager is indispensable. Light effects and any special features of the forthcoming show should be considered and tried out in conjunction with the rehearsal procedure described here.

Note that, as previously mentioned, adjustments in the timing of numbers must be confined to parts of the program other than the synchronized reels; the latter must always be run at standard speed, with the regulating switch on the motor control box set at REG.

The points to check are as follows:

1. On first reel of each synchronized feature picture and on first of each group of short subjects shown, determine how soon after starting motor fader should be brought up to its full setting.

It should be brought up slowly, taking two or three seconds, and should reach this point just before the voice or music begins. Add blank leader if necessary.

2. For remaining reels of a feature, determine how soon after change over fader should be brought up to its full setting.

Usually this will be immediately after change over.

3. For short subjects, determine how soon after end of voice or music accompanying each subject the picture should be faded out.

On second and following subjects, determine when motor of incoming machine should be started to allow proper time interval between subjects, and when fader should be brought up to its setting to catch incoming music.

4. If using a safety device that stops motor when film has run through, see whether there be any reels where the film terminates before the end of the record is reached, and add blank film at end as required.

5. As previously mentioned, in houses where the upper horns are of the 12-A type and the lower horns of the 13-A type, and where an output control panel is used, with a separate control for each horn, three different types of combinations or settings of the upper and lower horns are used, and designated respectively by the letters A, B and C.

The A, setting is for vocal and instrumental solos or speech and uses upper horns only or upper horns with some lower horn.

The B, setting adds more lower horn to bring out effect of orchestral accompaniment.

The C, setting is for orchestra alone and carries further result mentioned for the B, setting.

After setting up the record or film as directed, adjust the horns for an A, B, or C, setting as required for the particular subject being shown.

Inasmuch as the settings are determined by careful tests of the house, they should be followed without change. Other settings may throw the system out of balance electrically and overload it or distort sound.

6. As a matter of convenience, and in order to give the theatres the benefit of the opinion of the recording and engineering staffs, recommended fader and horn settings are frequently marked on records or films or given on cue sheets sent out with them.

Amplifiers are so adjusted that with a full house, and fader setting recommended, correct full house volume is obtained. With house only partially filled, fader should be brought down one or two steps.

7. Determine horn settings and empty house fader setting for each number, bearing in mind any recommendations marked on or accompanying record or film.

Do this with care and in particular do not permit too high a volume. Synchronized scores to feature pictures should be run at a volume appropriate to incidental music. Never make the volume so loud that it causes the needles to oscillate on the amplifier plate current meters. If this happen, it is a sure sign of overloading and poor quality.

Speakers talking at a distance or in conversational tones should be reproduced with less volume than those speaking close or obviously talking loudly. Instrumental solos should have less volume than full orchestras (not accompanying), bands, etc. In news reels, street noises, locomotive whistles, etc., should be loud to give correct illusion.

8. In certain records effect may be improved by bringing fader up or down a step at certain points in the picture, as just mentioned.

Even the horn settings may occasionally be changed during a number as record changes from light or vocal effects, which are best reproduced by upper horns, to heavier orchestra music for which lower horns are brought out. However, discretion must be used in not making too great or too frequent changes in horn and fader settings; each record is made under skilled musical and technical direction in such a manner that when it is reproduced the effect desired by composer, artist and conductor will be obtained without any need for frequently changing settings while playing. If they be changed too much, therefore, proper effect will not be obtained.

9. Having rehearsed show and determined all settings, curtain cues, etc., record them in the form of a cue card posted in the booth.

10. In communicating with the operator by means of the telephone set it will be found handy to use the buzzer with the following code:

One buzz.....Fader up one step.

Two buzzes.....Fader down one step.

Three buzzes.....Answer over telephone.

TEST QUESTIONS

1. *What fader setting should be used when the theatre is empty?*
2. *What is the proper film speed for pictures with synchronized sound?*
3. *How should the motor control box regulating switch be set?*
4. *How can the operator tell whether the sound is coming over properly?*

5. What should be done in the case of broken films?
6. Draw a diagram of a motor dynamo compensarc.
7. Describe the process of running synchronized subjects using either film or disc reproduction.
8. What is the procedure in running non-synchronized subjects?
9. Explain the use of the tilting mechanism.
10. How is the foot brake used?
11. Describe the method of rehearsing.
12. What is the buzzer signal code?

CHAPTER 200

Troubles During the Show

The projectionist should become familiar with the instructions given herein so that troubles may be quickly located and remedied thus continuing a programme with the minimum of interruption.

Whenever the sound is not coming over as it should, the fader can be employed to cut it out until the trouble has been located and remedied. It is much better to do this than to continue the sound accompaniment when it is obviously bad. If the fader be properly handled all kinds of trouble may happen and be remedied by the projectionist without the audience noticing anything seriously amiss.

Emergency Equipment.—Whenever trouble occurs, use the emergency equipment or emergency set up if one be provided and endeavor to locate and remedy the difficulty, if possible, by following the instructions given here. If unable to cope with the trouble notify the manufacturer of equipment to send a service man.

Fuses.—The installation has fuses at the following points:

Motor control box—Two 10 amp. plug fuses on *a.c.*

Two 15 amp. plug fuses on *d.c.*

Battery panels.

Box for film dry batteries—1 amp. midget fuses.

Horn cut out box (back stage)—3 amp. plug fuses.

46-A or 46-B amplifier (if used)—Two 3 amp. plug fuses.

KS-5321 motor generator (used on *d.c.* only)—

Generator—Two 10 amp. cartridge fuses.

Motor (115 V.)—Two 20 amp. cartridge fuses.

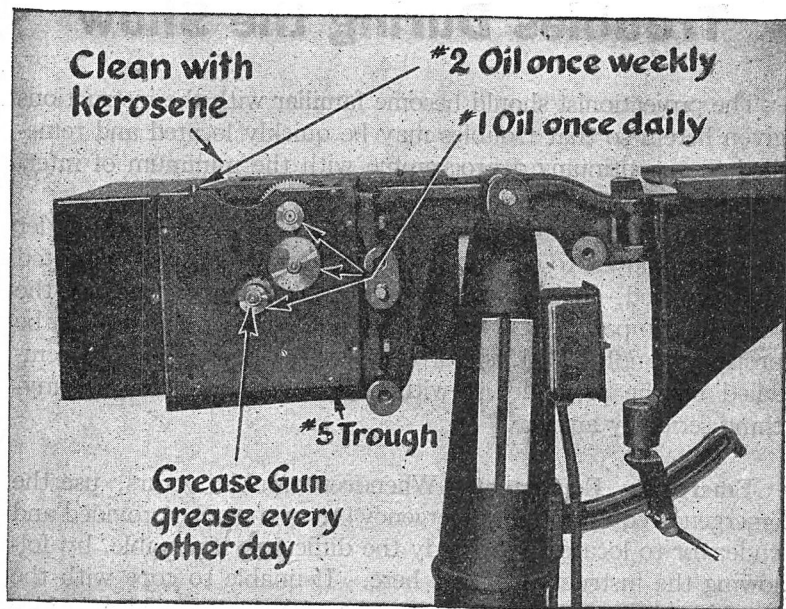


FIG. 7,913.—Pacent film head with oiling and greasing indications.

Motor (230V.)—Two 10 amp. cartridge fuses.

Volt meter—Two $\frac{1}{2}$ amp. midget type fuses.

Battery charger (used on *a.c.* only)—Three 5 amp. plug fuses.

If one of the fuses burn out, replace it by a new fuse of the same type, as covered in the instructions which follow, but if

it blow a second time, do not renew it until the cause of the trouble has been found and remedied.

Before removing the rear cover of any piece of amplifier equipment, be sure to turn off the power and keep it off until the cover is replaced. Also switch off the power on the battery switching and charging panel before replacing any fuses.

Testing Equipment for Faults.—If all conditions appear normal, and still no sound be heard from the horns, and no relief be afforded by any of the procedures that will be described, the indications are that a break or short circuit exists somewhere in the sound circuit. In this case listen in with the head set along this circuit, starting at the disc or film pick up with a record playing, and working on toward the horns until the location of the fault is shown by coming to a spot beyond which nothing is heard.

Be sure to use very little gain, as otherwise the head set will be overloaded and possibly damaged, and the quality will be spoiled. Use the same method to locate the source of noise or bad quality

Use a battery and buzzer to test lines for opens or shorts, but never to test amplifier or reproducer circuits, as this may upset the magnetic characteristics of the coils.

On some amplifiers two or more tubes are operated with their filaments in series; if one tube burn out, the others will then be extinguished. If two or more tubes go dark at once, therefore, it should be realized that only one has burnt out. This tube may be located by inspection, or the replacing tube can be tried in each socket in turn.

1.—Troubles Occurring while Testing

1. Charger not functioning (*a.c.* supply only).

a. On charger used with *a.c.* supply, if a rectifier bulb do not light, its filament may be burned out. Also a fuse on battery panel may have blown. Clean tube socket. If tube still do not light, replace it by one of spares supplied.

b. If tubes light but charger do not give output, a fuse inside charger may have blown

2. Motor does not start.

a. Is line switch on?

b. Fuse may have blown in motor control box.

3. Reading on motor control box meter not within specified limits.

a. If reading be too high, on *a.c.* or too low, on *d.c.* it indicates excessive friction at some point in mechanism. If this be not attended to immediately a bearing may freeze, rendering a projector temporarily useless. Stop machine and oil all bearings immediately abnormal reading is noted on meter, particularly any bearing that seems unduly hot. If trouble persist, notify manufacturer to send service man.

4. Motor does not maintain regulated speed.

a. Notify service man at once.

5. Unsteady pitch in reproducing (flutter).

a. With film reproduction, there may be dirt on the sprocket in the film compartment of the attachment. If this cause do not exist, notify service man at once.

6. Reproducer not tracking properly.

a. This occurs when needle jumps from groove. See that reproducer is not dragging on record, and that it is not hitting anything or otherwise being hindered from free movement. Put in new needle. Try new record. The swivel base on which the reproducer swings is mounted on a bracket, which in turn is clamped to the base by a bolt. See that the bracket is level and that the bolt has not loosened and allowed it to turn.

7. Excessive or insufficient plate current.

a. If this be noticed on testing the amplifiers, replace the tube showing this condition by a spare. When two or more tubes on an amplifier all show low plate current at the same time, try replacing the rectifier tubes on that amplifier (the 41-A amplifier uses the rectifier tubes on the 42-A amplifier). This may also be a sign of defective condensers (see paragraph *f* under heading, Volume falls off or ceases).

8. No sound from one horn.

a. Fuse may have blown in cut out box back stage.

b. If fuse in cut out box has not blown, replace receiver.

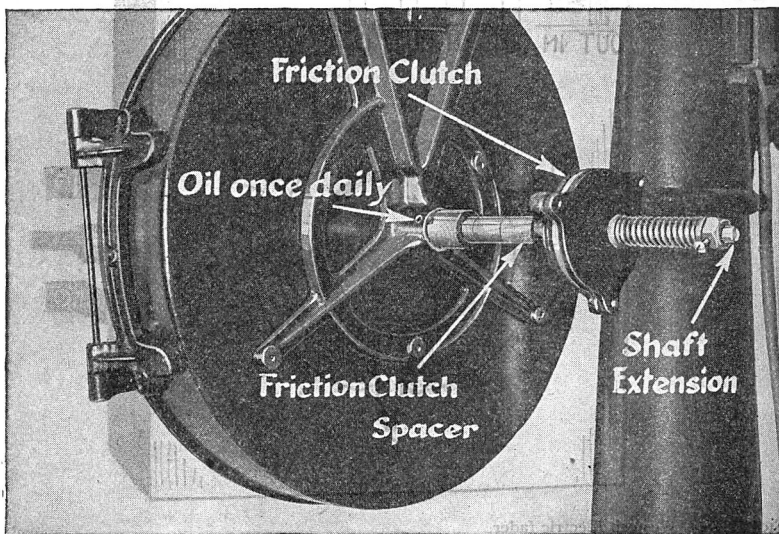


FIG. 7,914.—Pacent friction clutch spacer with oiling indications.

9. Volume falls off or ceases.

a. If system be a double one, having emergency amplifier equipment, cut in emergency amplifiers by means of key on system transfer panel. If this clear trouble, continue use of emergency amplifiers until a service man

repairs or replaces defective regular amplifier, unless trouble can be cleared as will now be described.

b. One of amplifier tubes may be burnt out. If so, replace with a new tube of same type.

c. One horn may have short in line or winding through which sound current passes, thereby causing others to receive no power. Turn off all horns by means of keys on output control panel, or if these be not provided, then by means of switches in horn cut out box back stage, and then try to locate

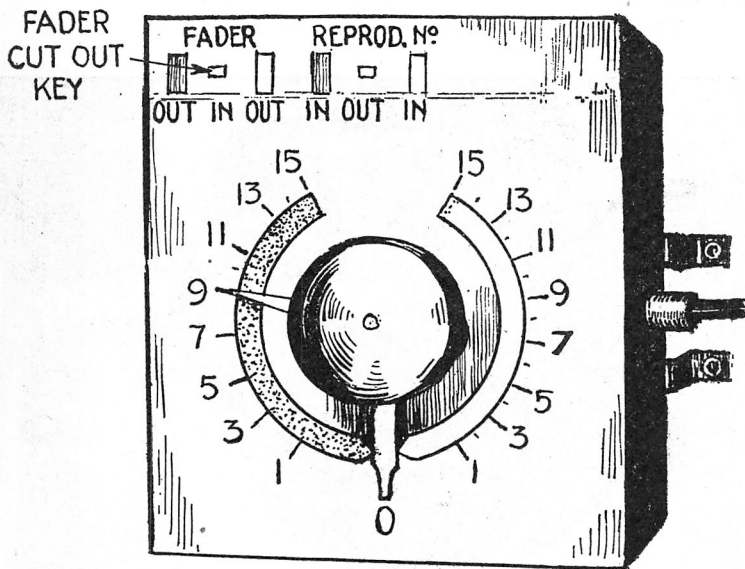


FIG. 7,915.—Western Electric fader.

bad receiver by turning horns on and off one at a time. They should all give volume except bad one. If defective receiver be found, replace.

d. Possibly fuses in horn supply circuit on battery panel have blown.

e. Check reproducers by switching from one to the other on fader. If one be bad, replace. If neither give any sound, check fader and circuit by means of head set, or as follows:

f. In systems using 41, 42 and 43 type amplifiers, left hand key at top of fader, called fader cut out key, fig. 7,915, can be used to cut out either side of fader circuit. If this key be thrown to left (red) for example, reproducing equipment on red machine will be connected direct to amplifiers without going through red side of fader. Similarly when key is thrown to right (white) side, white machine is connected direct to amplifiers. To check whether trouble be due to defect in fader, try using cut out key in this manner. If this eliminate trouble, use cut out key for change overs, instead of fader until service man can repair or replace latter. Regulate volume by means of gain control on 41-A amplifier.

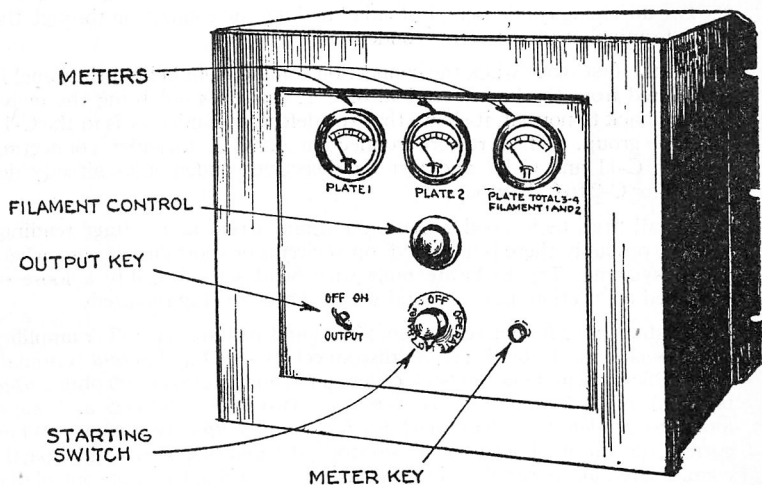


FIG. 7,916.—Western Electric type 46-B amplifier.

g. With film reproduction, exciting lamp may be out of focus or burnt out, or opening in photo-electric cell may be out of line with opening leading to film compartment. Position cell properly.

h. If system use one or more 43 type amplifiers, and plate current reading on one of these amplifiers is very low or is zero, probably a condenser has failed. A further indication of this is that plates of rectifier tubes of amplifier affected may begin to get red hot. Turn off power on this amplifier, by means of amplifier starting switch. Locate defective condenser as follows:

Remove front cover of amplifier. The condensers are connected in parallel in two groups, the first group containing C-2 to C-10 inclusive and the second group C-11 to C-19 inclusive. Unsolder connection coming from behind panel to lower terminal of C-2. Turn amplifier starting switch to *plate*. If plate meter reading be now normal, it shows bad condenser is in C-2 to C-10 group. Shut off switch. Restore connection on C-2 and unsolder connection between C-2 and C-3. Turn on switch. If meter reading be still normal, it shows C-2 is good and bad condenser is in C-3 to C-10 group. Restore connection on C-3 and unsolder connection between C-3 and C-4; test again with switch and meter, and so on until a condenser be found which when connected causes meter reading to fall. This will be the bad condenser. Cut it out by connecting together directly the lower terminals of the two adjoining condensers, instead of making the connection through the lower terminal of the defective condenser.

If in the first place when the connection coming from behind the panel is unsoldered from the lower terminal of C-2, this does not bring the meter reading back to normal, it shows that the defective condenser is in the C-11 to C-19 group. Then restore connection on C-2, unsolder connection between C-11 and C-12, and test for defective condenser as already described for C-2 to C-10 group.

i. If all fuses be in good condition and all current and voltage readings normal, probably there is a ground, open circuit or short circuit somewhere in the system. Try to locate fault with head set. Possibly a loose or grounded connection may be found which can be readily repaired.

If system have no emergency amplifiers and includes one 43-A amplifier and this is found to be defective, disconnect its *input* and *output* terminals (accessible by removing the back cover) and run system off 500 ohm *output* terminals of 42-A amplifier. If system use two 43-A amplifiers and one is found to be defective disconnect its *input* and *output* terminals. When cutting out an amplifier as just described the loss of power can be partly compensated for by running the fader higher, or raising the gain control dial on the 41-A amplifier one or two steps. Be careful not to impair quality by raising fader or gain so much as to overload amplifiers.

10. Poor quality or noisy output.

- a. See paragraph *a* under previous heading "Volume falls off or ceases."
- b. One of amplifier or rectifier tubes may be burnt out. Replace with spare of same type. For amplifier use, this must be a new tube.
- c. A receiver may be defective. Test horns one by one as described in paragraph *c* under previous heading.

- d. Film may be scratched or dirty.
- e. A reproducer may be defective. Test reproducers as described in paragraph *e* under previous heading.
- f. Fader may be defective. Check as described in paragraph *f* under previous heading.
- g. One of amplifier tubes may be defective. Take a new tube and try it in place of each tube in turn until the noisy one is located.
- h. Storage batteries may be dirty on top. See that they are kept clean. Storage batteries may have been put in use too soon after charging while

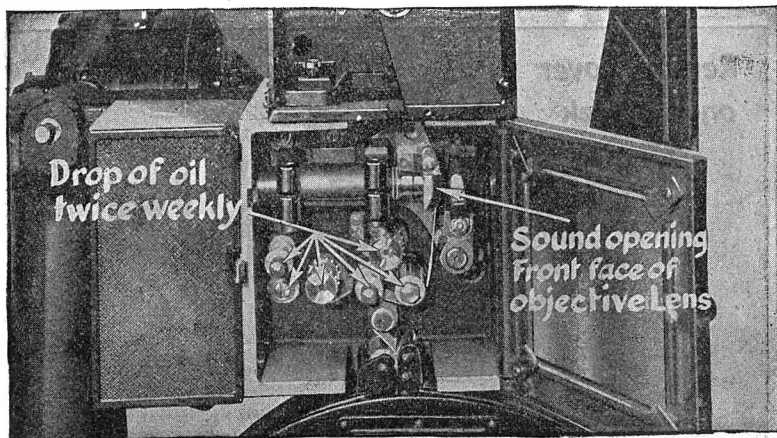


FIG. 7,917.—Pacent optical chamber with oiling indications.

still gassing. About half an hour is required for gassing to cease completely. Storage battery connections may be loose. Keep them tight.

i. There may be poor ground or loose connection at some point in system. Examine connections and tighten any found loose. If trouble be still unsolved, use head set, and if a defective 43-A amplifier be found, cut it out as described in paragraph *i* under previous heading.

11. Observer's equipment not functioning.

a. If not loud enough to enable observer and operator to hear each other, or if buzzer be weak or inoperative, make sure that switch on box is pulled

out, and that batteries are in good condition. Replace batteries (open battery box by loosening screw in cover). If trouble be not here, check line for shorts or opens.

12. Film breaks (Film reproduction).

a. As synchronism between pictures and sound is inherent in the film, no loss of synchronism is occasioned by a break. Therefore, deal with a broken sound film the same as with an ordinary film in the same circumstances, but in making splice be sure to follow directions given for Splicing Film.

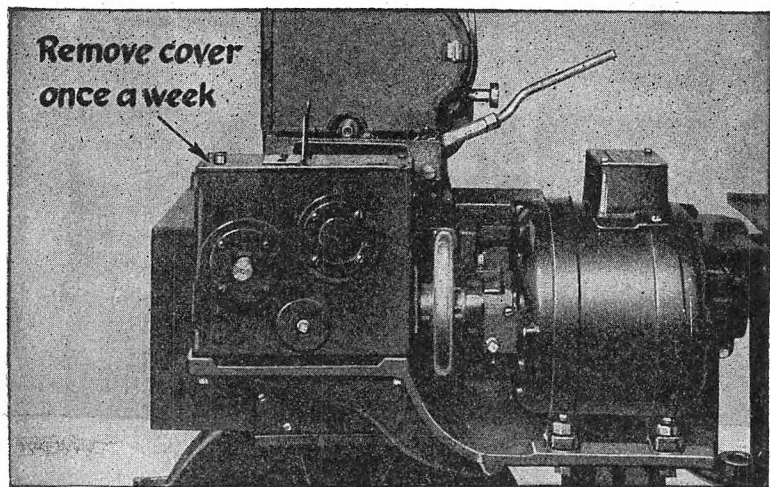


FIG. 7,918.—Pacent gear box with removable cover.

13. Film breaks (Disc reproduction).

a. Douse light, turn fader to zero and stop motor. The next step, as specified below, will depend on whether the break is above the intermittent or below it, and whether the sound only consists of a musical accompaniment and incidental effects, or whether there be speech, close ups, etc., which make synchronism very important.

b. Splice broken films.

14. Break below intermittent—all cases.

a. Run down film needed for winding around take up by means of hand wheel. Do not disturb film at aperture plate, or record and reproducer. Continue run, bringing fader to regular setting as soon as full speed is reached. Synchronism will usually be maintained under these conditions. However, since audience will lose some of the subject, it is generally better in the case of short subjects not to wait for re-starting as just described, but to continue performance immediately by showing next subject, which is set up on other machine. In the meantime broken film can be repaired and shown again at conclusion of number which is running on other machine. If break be near end of reel it may not be worth while returning to subject.

15. Break above intermittent—with speech or other sound accompaniment where exact synchronism is essential.

a. In this case it is not possible to continue on broken film without losing synchronism, and there is therefore no option except to continue program with next reel, which is set up on other machine, or else cut out sound for remainder of this reel.

16. Break above intermittent—with music or other sound accompaniment where exact synchronism is not essential.

Rethread and continue as previously described for break below intermittent. Synchronism is usually lost under these conditions, but this can be tolerated in an emergency, unless there be a direct cue in record, such as a knock, voice or cheers. In such a case, pass over cue with fader on zero.

17. Needle jumps groove.

a. If the needle jump back the sound will repeat, and may keep on repeating at every revolution of the record. If the needle jump forward, the sound will be ahead of the picture. The procedure will depend on the character of the film and on where the jump occurs. Any record on which the needle has jumped must never be used again, and the reproducer should be checked as soon as possible, when covered under "Troubles occurring while Testing—Reproducer not Tracking Properly." Bring fader to zero as soon as jump is noticed; the next procedure will depend on circumstances as follows:

With speech or other sound accompaniment where exact synchronism is essential. In this case it is not possible to continue without losing synchronism, and there is therefore no option except to continue program with next reel, which is set up on other machine, or else cut out sound for remainder of this reel.

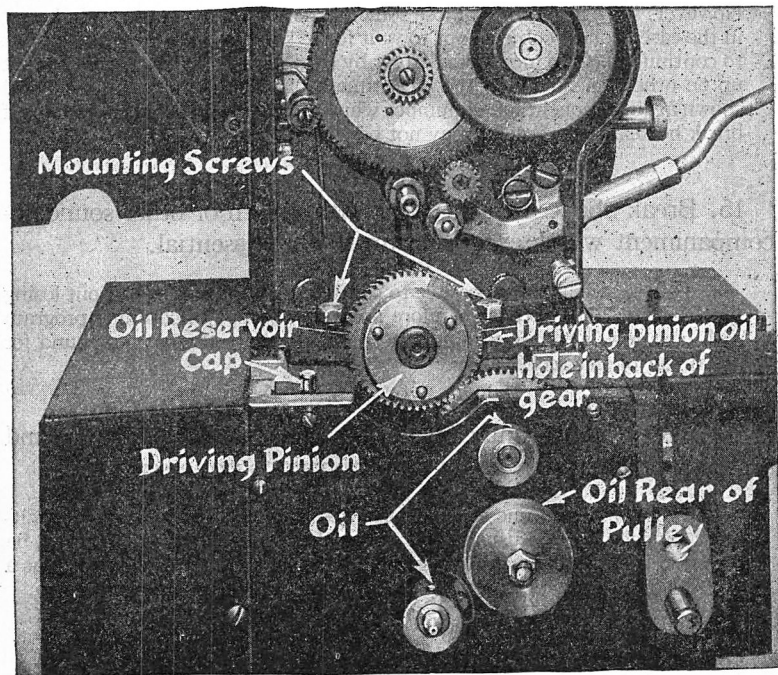


FIG. 7,919.—Pacnet driving pinion with oiling indications.

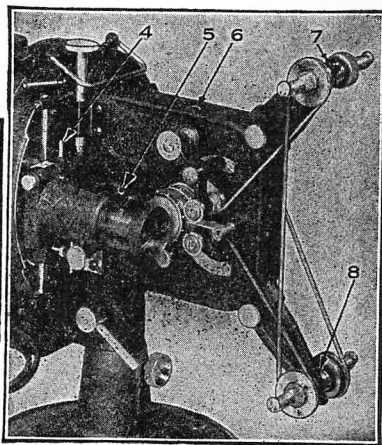
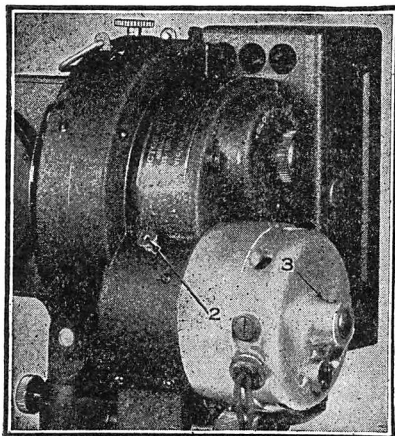
With music or other sound accompaniment where exact synchronism is not essential. Keep projector running, and look over reproducer quickly to see if there be any visible cause for jump, such as reproducer body dragging on record or reproducer hitting something that prevents it moving freely. If so, remove obstacle or change reproducer. This of course involves loss of accompaniment for remainder of reel.

If no cause for trouble be evident, then, if needle jumped back, change needle, move reproducer over to a position two or three grooves ahead of where it was when it jumped, and restore fader to its regular setting. If needle jumped forward and if it now seem to be tracking properly, restore fader to regular setting.

Synchronism is lost when record is continued after needle has jumped, so in such cases if there be any direct cues in picture, such as knocks, voices, cheers, etc., fader must be put down to zero when passing over them.

18. Quality goes bad or noisy and volume falls off or ceases.

See recommendations already made under these headings in previous section "Troubles Occurring while Testing."



FIGS. 7,920 and 7,921.—Victor Ciné projector with oiling indications. In fig. 7,920, locate and oil: 1, main bearing oil tube; 2, front motor bearing tube. Slide cover aside to expose hole; 3, rear motor bearing; in fig. 7,921, locate and oil: 4, cam bearing tube; 5, gear shaft (directly behind lens mount); 6, sprocket shaft tube; 7, upper reel shaft; 8, lower reel shaft; 9, rewind pulley hub.

TEST QUESTIONS

1. When sound is not coming over properly, what should be done?
2. What may be said of the emergency equipment?
3. Where should fuses be installed?
4. Describe the method of testing the equipment for faults.
5. Give a list of eighteen troubles occurring while testing and explain in full the various remedies to be applied.



CHAPTER 201

Technicolor

Technicolor.—This is a process for photographing pictures *in their natural colors*. The process as described by Cameron is briefly as follows:

An especially sensitized negative is run through a camera which photographs simultaneous pairs of pictures; one member of the pair recording all the warm tones of the original scene, the other member of the pair recording all the cold tones of the original scene. These color records appear on the negative in black and white, that is to say, in varying densities of black silver, just like any other negative.

The color records are transferred from the negative to a positive by the usual photographic procedure. These positives are then colored with dyes, one with warm colored dye and the other with cold colored dye. These two, when superimposed, recreate the original scene in both its warm and cold tones.

Needless to say the actual camera filters and the actual pigments used in the positive process are very carefully selected and balanced to give brilliant primary colors as well as the softer intermediate tones.

The original technicolor process resulted in a positive film which had the two companion images on opposite sides of the film. This naturally required special attention on the part of the operator to make sure that what ordinarily is the celluloid side of the film was not being rubbed or abraded in any way in his machine; since such abrasion would be affecting one of the emulsions of the technicolor film. Furthermore, to show the images of the two sides of the film to maximum advantage, it was desirable that the projection lens be racked forward slightly. The added emulsion also caused a slight increase in thickness of the film which gave it a flexibility somewhat different from ordinary film and also made it desirable to have film gate tension on the projector somewhat looser than normal. These differences are characteristic of all double coated stock.

For the past year technicolor release prints have been made by a new and improved process wherein both images are embedded in one emulsion so that the resultant film is mechanically like a black and white film. The advantages of this improvement will be obvious to the projectionist. What corresponds to the emulsion in this new film is a very hard and glassy looking gelatin so that the appearance of the film in the hand is a little different from black and white and care must be taken to distinguish the celluloid side from the gelatin side. To assist the operator, all technicolor prints have a little red tab at the side of the picture. When holding the film in the hand with the little tab at the left of the picture the gelatin side is then facing you. When splicing this film, care must be exercised to see that the especially hard gelatin is entirely scraped away where the patch is to be made.

TEST QUESTIONS

1. *What is technicolor?*
2. *How do color records appear on the negative?*
3. *How are color records transferred from the negative to a positive?*
4. *Describe the original technicolor process.*
5. *Explain the new and improved process.*

CHAPTER 202

Booth Wiring for Projectors**Kinebooth Wiring 1**

In the preparation of this chapter the author has had the able assistance of Mr. Alvin Seiler, Director of Engineering of the National Theatre Supply Co., New York City.

To become a good booth wireman, it is necessary to have a thorough knowledge of the various items of apparatus and equipment to be installed in the booth and to be familiar with the functions thereof, so that the wiring can be properly installed to meet the requirements of the various pieces of apparatus. Since all the apparatus has been described in other chapters, it is unnecessary to go into that part of the subject here.

The simple elements comprising the light projector system are:

1. The light source.
2. The lens system;
3. The screen or reflecting surface.

The simple process employed is to introduce an object of

NOTE.—Because of the many instances in which a misnomer has been applied to designate the room in which motion picture projectors, stereopticon projectors, effect projectors, spotlights, and auxiliary apparatus and equipment are located, the word *kinebooth* has been adopted and accepted by architects and engineers to define that particular section of a building.—Seiler.

NOTE.—To aid those operating series arcs, the author includes such arrangement in this Chapter, although the present practice is to wire the arcs in *multiple*. See Chapter 204 for additional *multiple arc diagrams*.

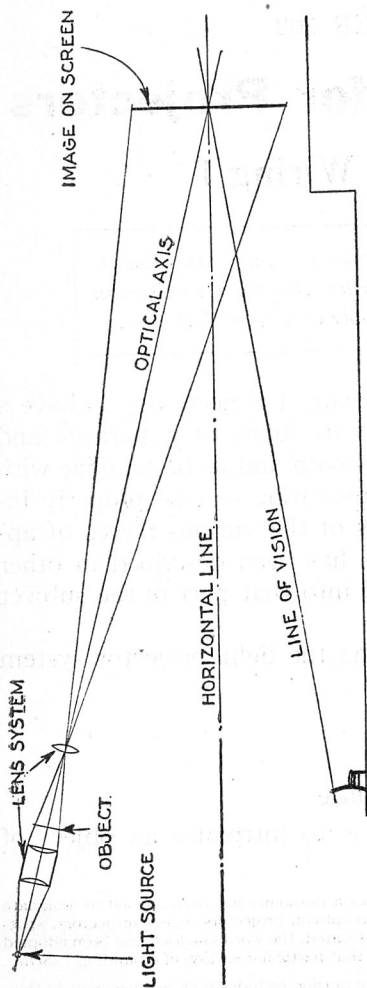


FIG. 7,922.—Diagram illustrating proper placement of projector and screen.

variable density ranging from opaque to transparent (or opaque and transparent for black and white projection, or color mediums as desired), between the light source and the lens system projecting the image against a screen or reflecting surface.

The ideal and most efficient plan of location of the apparatus comprising the simple elements would be to place the projector slightly above the horizontal and to have the audience seated slightly below the horizontal, as shown in fig. 7,922. As structural building conditions do not always permit the ideal arrangement, this and many other factors naturally govern the results to be obtained from a light projector system just described. The following are some of the primary factors:

1. Quality and intensity of light at source.

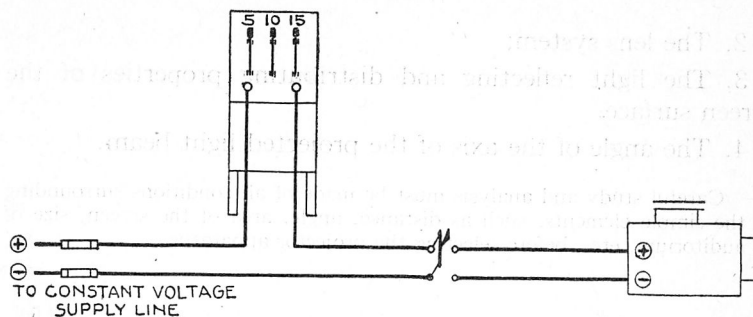


FIG. 7,923.—Hertner wiring diagram showing method of connecting type AA, and A ballast rheostats.

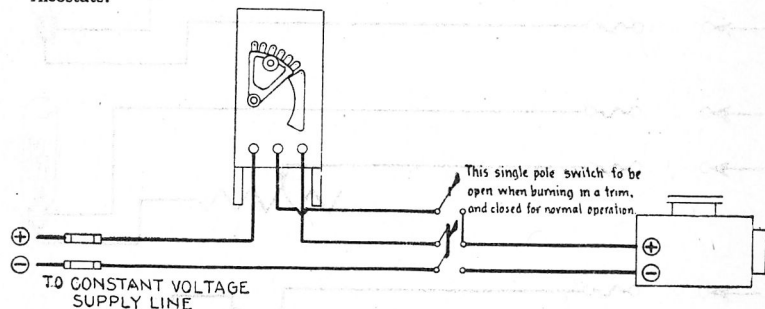


FIG. 7,924.—Hertner wiring diagram showing method of connecting types G and H ballast rheostats.

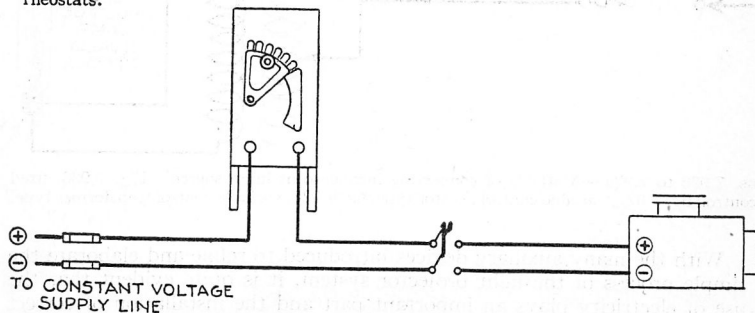
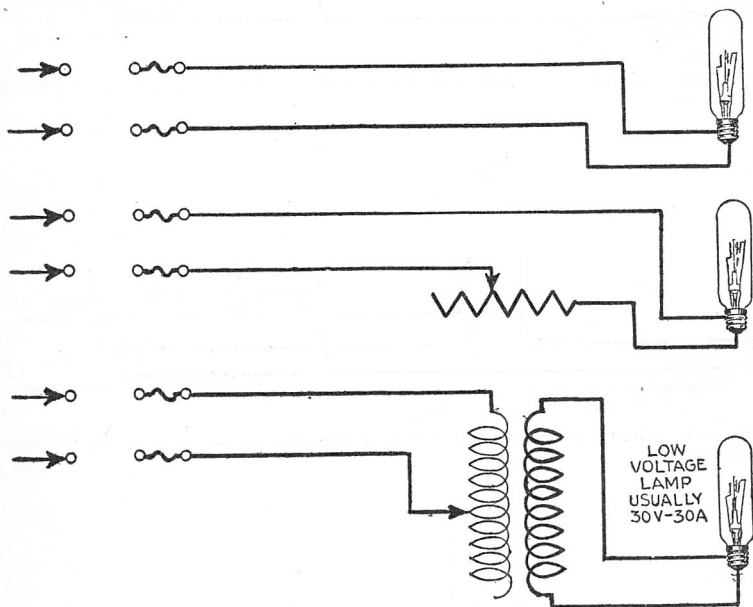


FIG. 7,925.—Hertner wiring diagram showing method of connecting types B, C and D, ballast rheostats.

2. The lens system;
3. The light reflecting and distributing properties of the screen surface.
4. The angle of the axis of the projected light beam.

Careful study and analysis must be made of all conditions surrounding the simple elements, such as distance, angle, area of the screen, size of auditorium, etc., before selecting the projector apparatus.



FIGS. 7,926 to 7,928.—Methods of connecting incandescent lamp source. Fig. 7,926, fixed control; fig. 7,927, variable control resistor type; fig. 7,928, variable control transformer type.

With the many auxiliary devices introduced to refine and elaborate the simple process of the light projector system, it is quite evident that the use of electricity plays an important part and the installation of correct and adequate wiring is most essential. Each application presents distinct and individual problems and no fixed rule or plan of wiring can be given.

Booth wiring in general is usually divided into five sections:

1. Projector wiring for projector light source

- a. A.c. wiring;
- b. A.c.—d.c. wiring;
- c. D.c. wiring.

2. Light wiring;

3. Power wiring;

4. Sound system wiring;

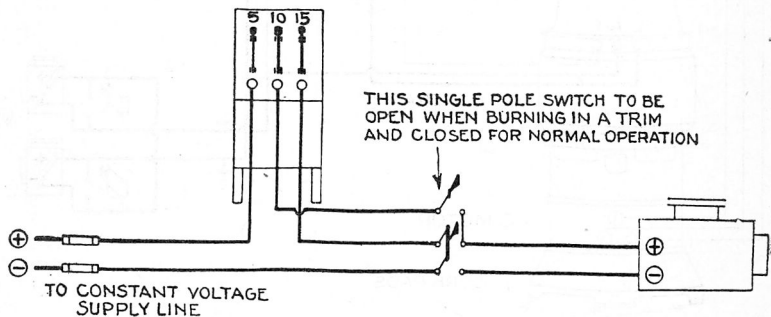


FIG. 7,929.—Hertner wiring diagram showing method of connecting types J, K and L, ballast rheostats.

5. Signal system such as phones, buzzers, indicators, etc.

This chapter treats only of projector wiring, the sound system wiring being presented in Chapter 203. Considerable information on theatre wiring in general being given in Chapter 204 in question and answer form.

A. C. Wiring.—Where incandescent lamps are employed as the light source the connections for each projection unit are made as shown in figs. 7,926 to 7,928.

When two or more projector units are installed, the wiring shown in these diagrams is done in respective multiples and

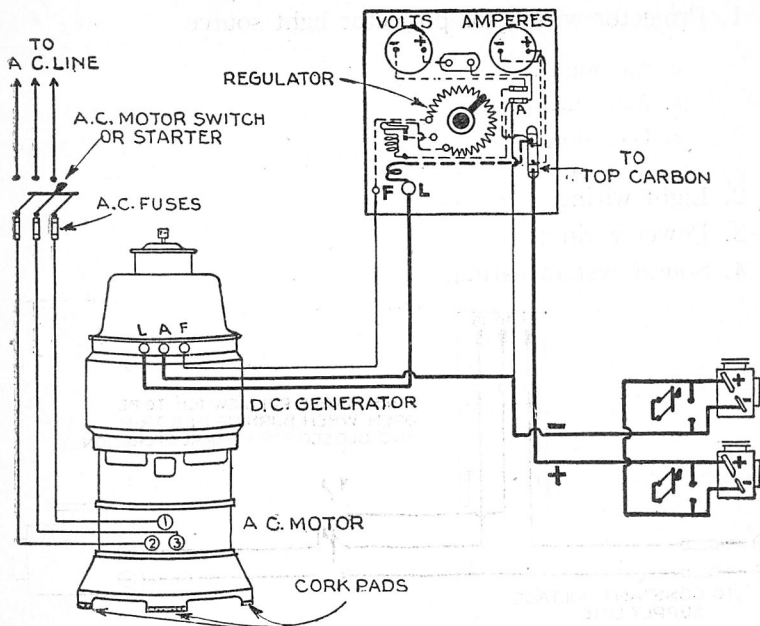


FIG. 7,930.—Wiring diagram of double arc three phase transverter with control panel. Transverter should be on a floor that is free from vibration. It is not necessary to bolt it down. Set the machine on the four cork pads which are provided for this purpose. **Wiring.** Make connection from the a.c. line service to the starting switch and from the starting switch to motor terminals as shown. On two or three phase equipment close the switch and make sure that the armature rotates in the direction indicated by the arrow on the top cap. If the armature rotate in the wrong direction, it must be corrected by reversing the leads to one phase of the motor terminals. Single phase equipment will always start in the proper direction when connections are made according to the diagram. **Caution.** Do not change connections inside of transverter unit to correct direction of rotation or polarity. The machines are all checked up complete with their equipment when tested. The motor must be connected to proper side of the line and connections to panel must be made correctly to bring polarity of the instruments and lamp carbons correct. **Fuses.** Fuse the a.c. motor side of these machines only. The d.c. generator circuit does not require fuses or switches other than on wiring print accompanying the machine. The a.c. fuses at the a.c. motor starting switch must be of large enough capacity to carry the maximum load of the machine. Fuse according to voltage of line service. **Wiring to lamps.** Use wire of size proper for capacity of machine to connect from L and A, on the transverter to panel board, and lamps. No. 14 or No. 12 size wire may be used to connect F, on transverter to the F, on the field regulator in panel board.

distribution to the units is made from the *a.c.* panel board preferably located in the kinebooth. Miscellaneous branch circuits may also be taken from the panel board thus comprising a simple wiring system.

Incandescent projector lamps are adaptable only to installations where a small picture is desired and the distance to the screen is short, rarely in excess of fifty feet.

These installations are usually made in small schools and auditoriums

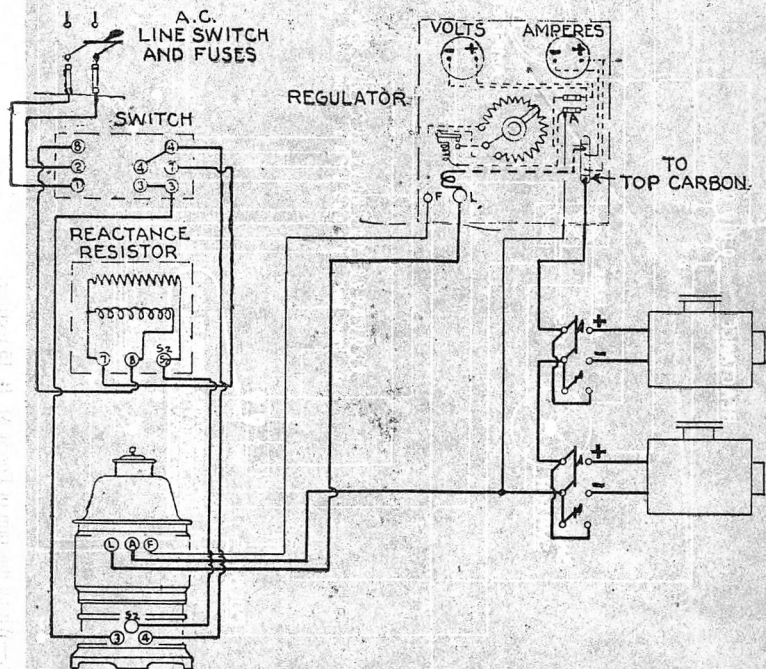


FIG. 7,931.—Wiring diagram of double arc *single phase* series arc transverter with control panel. To start throw the handle of the switch to the position marked *start*. Hold there until unit comes up to speed, then throw over to position marked *run*. The starting time is approximately 20 to 30 seconds.

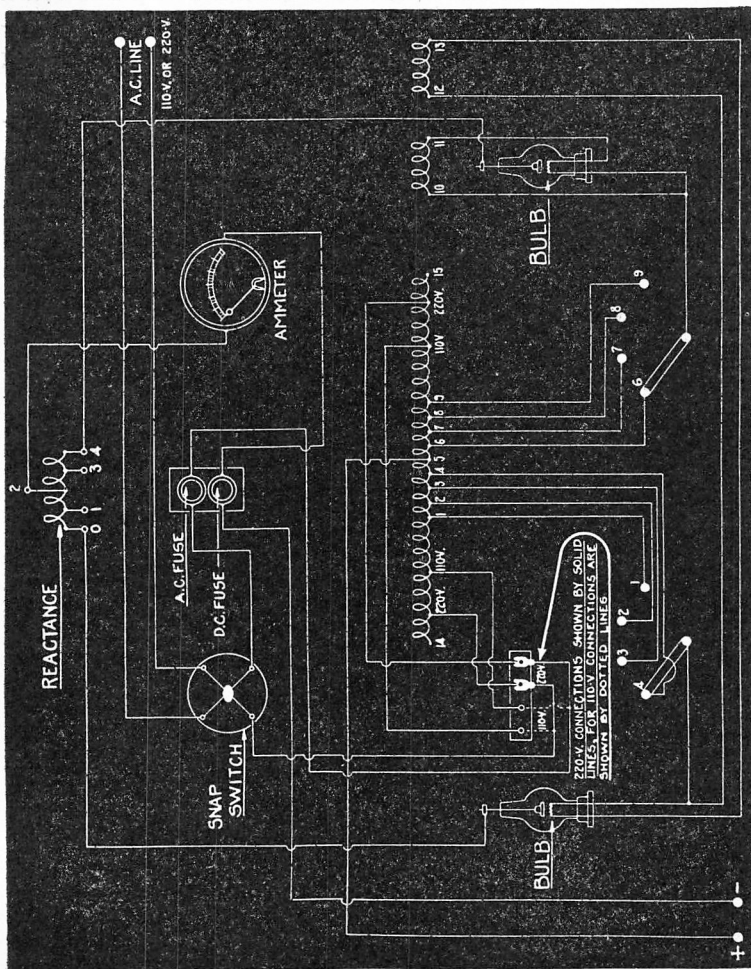


FIG. 7,932.—Wiring diagram of Forest M. P. 15 rectifier.

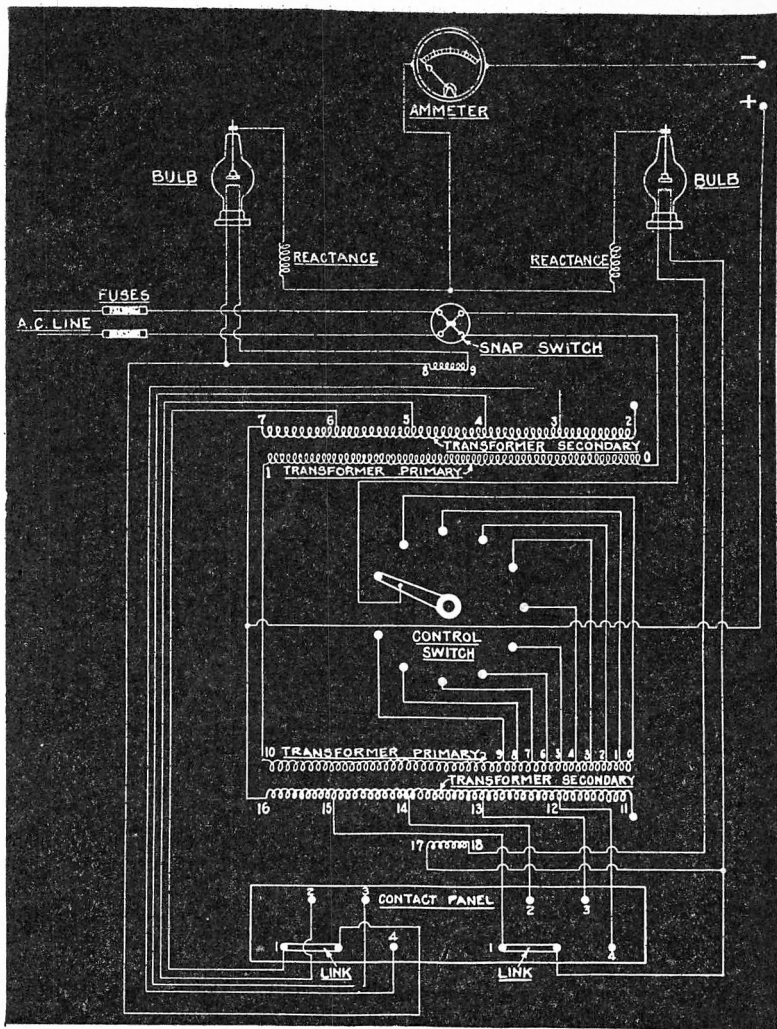


FIG. 7,933.—Wiring diagram of Forest M. P. 30 rectifier.

and the commercial use in small theatres is being abandoned. When incandescent lamps are operated on *d.c.* circuits, connections as shown in figs. 7,926 and 7,927 are used.

A. C.—D. C. Wiring.—As the size of the picture and the distance to the screen increases, greater demand is made on the light source. The next step is to employ an arc lamp. Alternating current at the arc results in an unsteady and flickering light. Direct current at the arc results in a steady light and as the temperature at the positive carbon is greater than at the

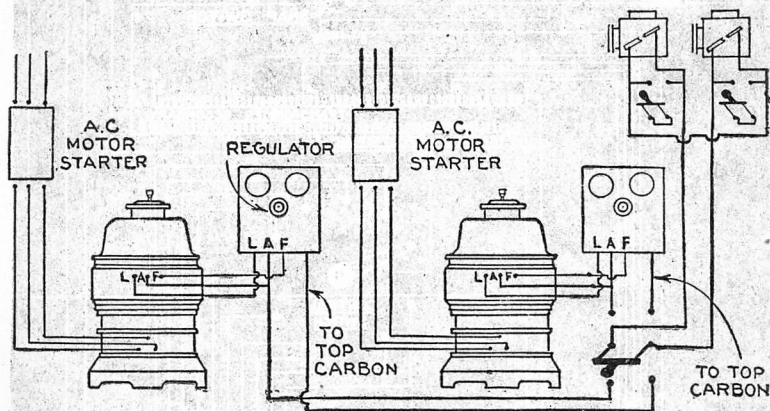


FIG. 7,934.—Wiring diagram for two double arc transverters connected for emergency use.

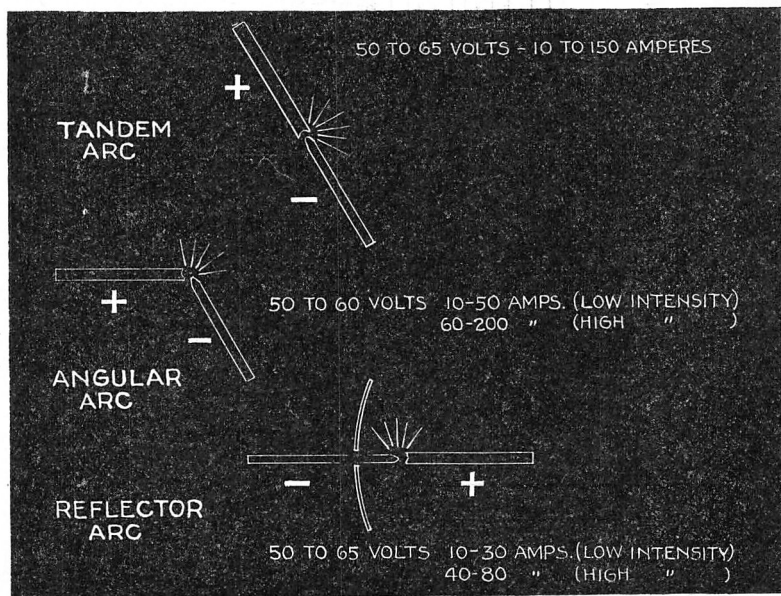
negative carbon, the light is generated at a concentrated point which is an advantage to the optical or lens system.

When the *d.c.* demand is low, an *a.c.* to *d.c.* rectifier with ballast characteristics is sometimes employed for each projector unit. This wiring diagram is shown in fig. 7,932.

When two or more projector units are installed, the wiring is done in multiples as previously described, and the *a.c.* distribution system remains the same.

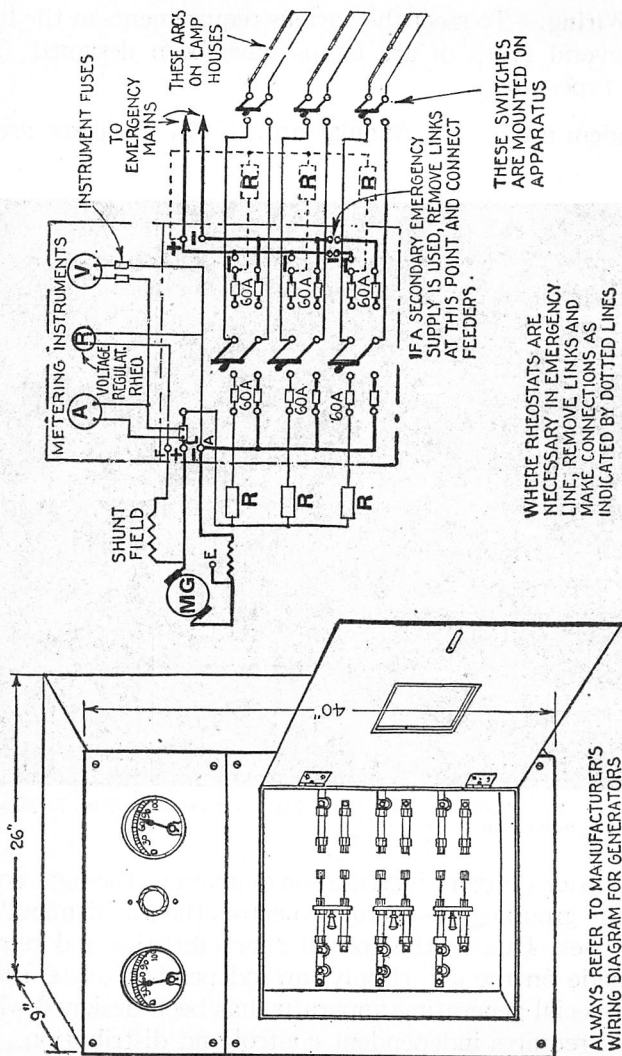
D. C. Wiring.—To meet the various requirements at the light source, several types of arc lamps have been designed. The standard types are:

1. Tandem arc.
2. Angular arc.
3. Reflector arc.

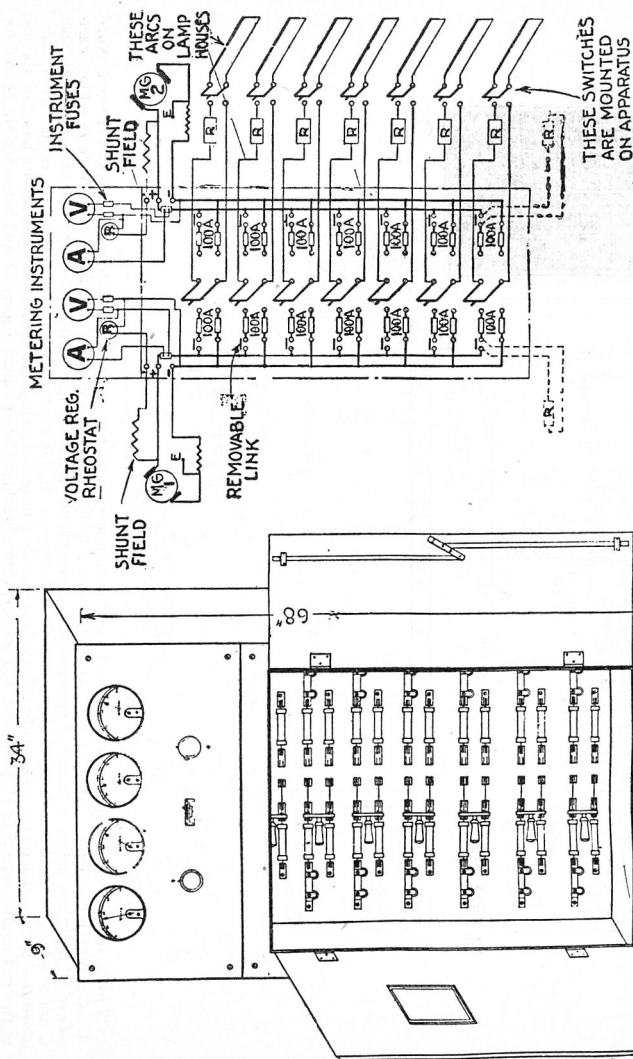


FIGS. 7,935 TO 7,937 —Various projector arcs. Fig. 7,935, tandem arc; fig. 7,936, angular arc; fig. 7,937, reflector arc.

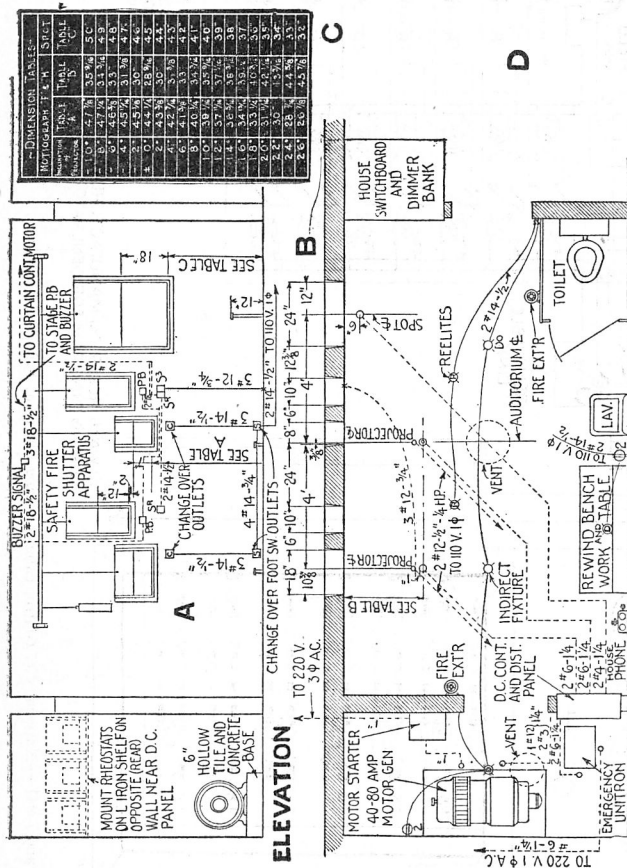
As conditions further increase the demand at the light source and by the grouping of several projectors the *d.c.* demand continually rises. Due to the special characteristics and requirements made on the *d.c.* supply, an independent system is desirable. Special generating apparatus has been designed which, of course, requires independent control and distribution.



Figs. 7,938 and 7,939.—National d.c. control cabinet and wiring diagram, type SG-63.



Figs. 7,940 and 7,941.—National d.c. control cabinet wiring diagram, type DG-107.



Figs. 7, 942 and 7, 943.—Typical kneebooth layout for motiograph machines, types F and G, and Brenkert spot C-4 or equal. **Note A.**—Cut both projection apertures $18^{\circ} \times 7^{\circ}$. If stereopticon attachment is to be used on both machines, **Note B.**—Flare each side of all apertures to line with side of proscenium arch, and slope bottom to line with foot. **Note C.**—Dimensions in table C are based on ϵ of spot lens being 48° from floor (O inclination). If this distance be more or less, add or deduct from table. **Note D.**—Information on the layout is to convey data regarding projection equipment only. Dimensions are based on the use of two motiograph type F or H, projectors and one spotlight (Brenkert C-4 or equal) generator and wire sizes are figured for low amperage reflector arc lamps on the projectors, and with not over 50 amp. on the spotlight.

The wall space available in the kinebooth being limited, it is desirable to lay out the wiring system as compact and efficient as possible. This can be effectively accomplished by combining the control and distribution in one cabinet as shown in figs. 7,938 to 7,941.

Location.—After a thorough analysis of the requirements is made, a complete detailed drawing showing the exact location of each piece of apparatus should be prepared. This drawing serves as a guide to the wireman on the job and as a check against the electrical and structural requirements of the kinebooth. Figs. 7,942 and 7,943 is an example of a small kinebooth plan designed for installation of two motion picture projectors (without sound equipment), one small spotlight, one motor generator, one *a.c.* to *d.c.* rectifier for emergency use, etc.

Figs. 7,944 to 7,947 is a plan designed for installation of two motion picture projectors (with sound equipment), one double lamp house dissolving lantern slide and effect projector, one heavy duty spotlight, two motor generators, switchboards, dimmer bank, etc.,

Auxiliary Equipment.—There is usually a considerable amount of auxiliary equipment installed such as, rewind apparatus, film renovating machine, inspection and rewind table, carbon racks, film vaults, supply cabinets, fire extinguishers, etc., some of which occupy wall space and careful consideration should be given to the location of these items so that electrical outlets can be provided where needed and that the wall space is properly allocated.

Light Wiring.—This section covers the wiring for small motors, general lighting, reelite inspection lamp, plug receptacles, etc., where the demand is under 1500 watts per circuit and it is good practice to provide a separate regulator type of

panel board to take care of the kinebooth requirements only and not to connect these circuits to any panel board outside of the kinebooth. Always provide a liberal number of spare circuits for future requirements.

Power Wiring.—This section covers the wiring necessary for all motors one *h.p.* and above, such as motor generators, ventilating equipment, heavy duty curtain control, etc. This is done in the standard practice of wiring; feeders and branches are run from the power distribution switchboard to the line switches thence to starters and motors.

The control should be located in the kinebooth and as wall space is limited, remote control starters should be used in almost all instances. It is good practice to provide the feeders and branch circuits in double the size of rated requirements as in many instances a change in equipment in the kinebooth places unusual demands on the wiring system.

Sound Wiring.—This section is covered in Chapter 203.

Signal System.—A complete signal and communication system should be installed in every kinebooth. An intercommunicating telephone system is most essential. This should connect with the stage, dressing rooms, orchestra leader, ticket booth, manager's office, etc.

It is also desirable to supplement this with a signal system of buzzers, drops or pilot lights between the stage director, stage electrician, orchestra leader, etc., as a means of conveying cue signals to control the operation of the various apparatus. This wiring should be done in multi-conductor lead covered cable with sufficient spare conductors provided for future requirements.

Conclusion.—From past experience it has been observed that in the advancement made in design and application of various types of light projector apparatus, continued increase has been

made on the demand for electric current not only in load requirements but in electric current of various characteristics. The introduction of sound with the motion picture has brought with it a sensitive and complex system of wiring. Satisfactory operation of all the combined equipment depends on the proper supply of electricity at points of demand. Therefore, the electrical wiring should be installed in the best manner possible with materials of highest quality.

Tight connections, well soldered joints, good insulation, shielding and guarding of conductors are all very important. Many responsibilities are placed on the electrical contractor and wireman. It is advisable to consult with a reliable and experienced engineer and be guided by one person in directing the installation of the wiring and equipment.

TEST QUESTIONS

1. *Name the simple elements of the projector system.*
2. *Mention five provisions of kinebooth wiring.*
3. *What is the proper placement of a projector?*
4. *Name the various controls for incandescent lamp source.*
5. *What are the conditions requiring a.c.-d.c. wiring?*
6. *How are ballast rheostats connected?*
7. *Name three kinds of arc.*
8. *Describe light and power wiring.*
9. *Draw a diagram of double arc, single phase, series arc transverter with control panel.*
10. *Draw a diagram of a multiple arc three phase transverter with control and distribution panel.*

CHAPTER 203

Booth Wiring for Sound

Kinebooth Wiring 2

To illustrate the method of wiring sound reproducing apparatus the RCA Photophone system is here presented.

Generally speaking, RCA Photophone sound reproducing equipment is divided into two general classes:

1. Equipment with power supply for amplifier racks furnished by motor-dynamo sets.
2. Equipment with power supply obtained wholly, or in part from vacuum tube high voltage rectifiers.

These equipments are known respectively as SPU (socket power unit) and MG (motor dynamo) equipment. Representatives of these two classifications are the PC-10 equipment and the PG-13 equipment which will be described in more detail in the following paragraphs.

Type PG-13 Equipment.—This is the motor-dynamo operated equipment consisting of an amplifier with a motor generator set for power supply, two sound heads, two synchronous discs, one booth monitor and one stage speaker with directional baffle. Ordinarily, it is intended that this equipment be completely installed in the projection room, with the exception of the stage speakers, of course.

All power for the type PG-13 equipment is supplied by a three unit motor dynamo set. One dynamo is 600 volts, and supplies all plate and photo-cell polarizing voltages.

The second dynamo delivers the current at 12 volts for the exciter lamps, tube filaments, monitor speaker field and stage speaker field. The

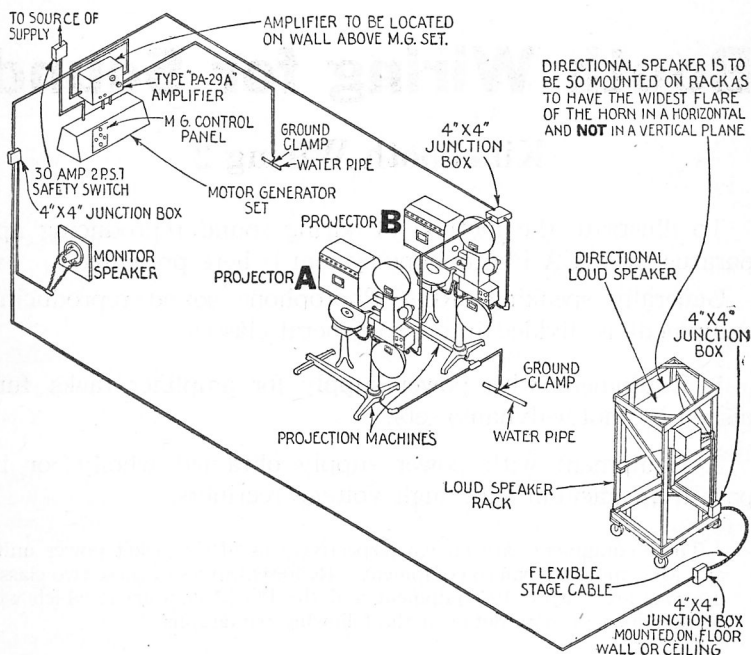


FIG. 7,948.—General layout of a typical RCA type PG-13 installation showing inter-apparatus conduit runs.

12 volt machine is excited from the 600 volt machine. For standard equipment the motor is a 115 volt, single phase, 60 cycle machine. Whenever necessary, a 110 volt *d.c.* motor and *d.c.* projector motors are supplied.

The dynamo set is enclosed in a metal cage approximately 48 ins. by 18 ins. by 30 ins. high. This cage is made so that the front and back are removable by taking out about one half dozen thumb screws. The motor

dynamo set is mounted on a separate base and is not mechanically connected to the cage base.

Type PG-13 Control Panel.—This is built on to the motor dynamo set and is an integral part of it. This panel is mounted at the middle of the motor dynamo set and stands approximately 1 ft. off the floor, flush with the metal cage.

The controls on this panel consist of field rheostats, starting switch and two meters. The meters indicate the two voltages which are controlled by the field rheostats. The rheostats are built in tandem with a single knob similar to that used on broadcast apparatus. The knob is pushed in to turn one rheostat, and is pulled out to turn the other.

Turning on the starting switch puts the dynamo set in operation, and consequently places the whole set in operating condition. The dynamo set itself is mounted on a felt base, which is fire proofed. This is provided to eliminate noise due to vibration of the machine.

Type PG-13 Amplifiers and Tone Control.—The amplifier unit consisting of voltage and power amplifiers, is built into a single unit somewhat similar in its general appearance to the socket power unit amplifier.

The voltage amplifier is made up with a combination of transformer, resistance and impedance coupling. It consists of three stages using UX-112A tubes.

The power amplifier consists of four UX-250 tubes operating in parallel push-pull.

In addition to the amplifier proper, there is a separate filter unit for filtering the plate supply and polarizing voltages. The entire amplifier is contained in a cabinet which measures approximately 22 ins. by 22 ins. by 10 ins. deep. This cabinet is designed for mounting on the wall. In addition to the amplifier and filter units, the amplifier cabinet contains a volume control and compensating unit.

The relay type of fader is used and the amplifier cabinet is provided with pilot lights to indicate which projector is in operation. The amplifier has practically the same input terminal connections as the type PG-10. The output circuit of the amplifier has been designed to operate a single stage loud-speaker and a dynamic monitor, although, by making the

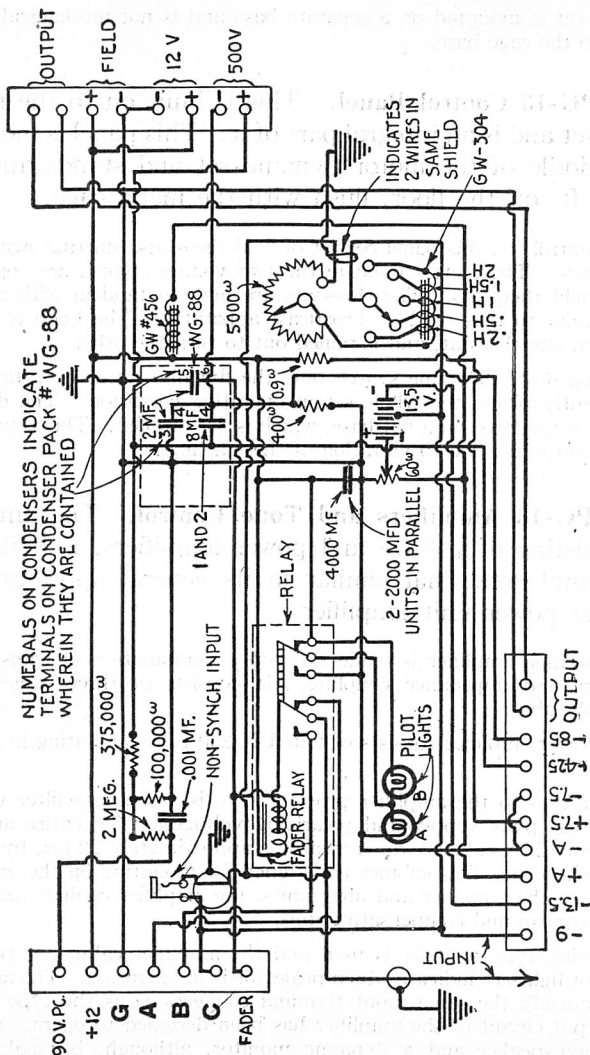


FIG. 7,949.—Wiring diagram of RCA type PG-13 sound equipment filter unit.

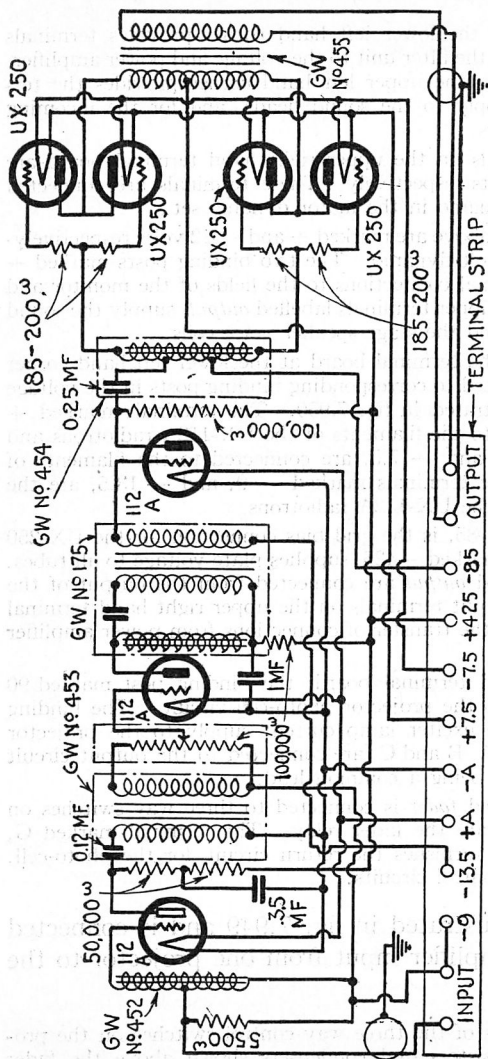


Fig. 7,950.—Wiring diagram of RCA type PG-13 sound equipment amplifier unit.

proper connections, two or four loud speakers may also be used. A phonograph input jack has been provided for the use of a non-synchronous phonograph.

Wiring for Filter Unit.—Fig. 7,949 illustrates the wiring of the filter unit used on the type PG-13 equipment. Three terminal boards are provided.

The one in the upper right hand corner provides for the connection of the filter unit to the motor dynamo set which supplies all power to the type PG-13 equipment, and also for the connection of all loud speakers.

The terminal board in the lower left hand corner provides terminals for the power supply from the filter unit to the voltage and power amplifier, and the terminal board in the upper left hand corner provides the terminals for the power supply to the sound heads, and for the incoming signals from the projectors.

The two lower terminals on the upper right hand terminal board are marked + and — 500 volts respectively. These terminals are connected direct to the 600 volt dynamo in the motor dynamo set.

The next two terminals above are marked + and — 12 volts respectively, and are wired to the 15 volt dynamo. The two binding posts marked + and — field, are for external connections to the fields of the monitor and stage speakers. The two upper terminals labelled *output*, supply the sound currents to the monitor and the stage speaker voice coils.

The binding posts on the terminal board at the lower left-hand corner of the diagram are connected to corresponding binding posts in the voltage and power amplifier illustrated in fig. 7,950. The terminals marked + and — A, are connected to the filaments of the UX-112A radiotrons and the terminals marked + and — 7.5, are connected to the filaments of the UX-250 tubes. The terminals marked — 9, and — 13.5, are the grid bias connections for the UX-112A radiotrons.

The terminal marked —85, is the grid bias connection for the UX-250 tubes while the terminal marked +425, supplies plate voltage to all tubes. The two terminals labelled *output* are connected from the output of the power amplifier to the output terminals on the upper right hand terminal board and are merely for the transfer of connections from power amplifier to speakers.

On the upper left hand terminal board, the binding post marked 90 volts, is the power line to the projector photo-cell circuit. The binding post marked +12, is the exciter lamp current supply to the projector sound heads. Terminals A, B and C, are connected to the output circuit of the two projectors, C, being a common lead.

The binding post marked *fader* is connected to three way switches on the projectors which operate the fader relay. The terminal marked G, is a common ground and furnishes the return circuit for the photo-cell, exciter lamp, and fader control circuits.

The fader relay is illustrated in fig. 7,949 and is connected so as to transfer the amplifier input from one projector to the other.

It is operated by means of the three way control switches on the projector. The group of resistors and condensers shown above the fader

relay are used for the purpose of protecting the equipment in the case of a defective photo-cell or some other defect in the projector's photo-cell circuits.

These resistors also act as a filter to give the desired output characteristic to this circuit.

The condenser block shown to the right of the relay is made up of two 2000 microfarad electrolytic condensers and is used to smooth the ripple in the 15 volt dynamo supply. Below this condenser is the potentiometer connected across the filament of the UX-112A's which is used for hum elimination.

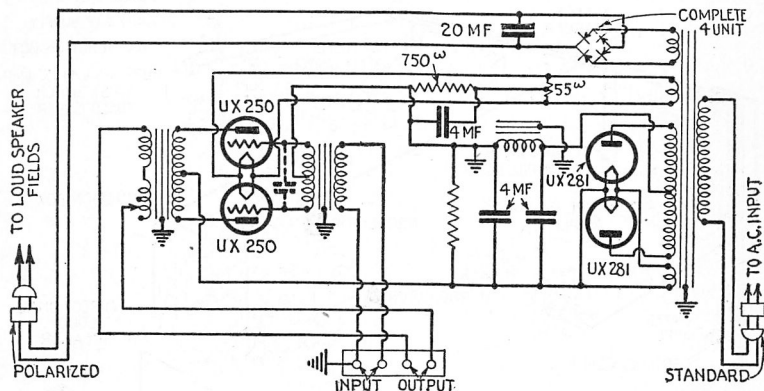


FIG. 7,951.—Wiring diagram for power amplifier. *Note:* Capacitor pack (3-4 mf. cond. 1-20 mf.). New SPU-62 includes 50 mmf. condenser across secondary of input transformer, also large radiating plates for Rectox.

The power amplifier illustrated in fig. 7,951 is used in all Photophone SPU equipment.

The larger the equipment the more power amplifier units are used. An examination of fig. 7,951 will show that its grid, plate and filament voltages are totally derived from its own power unit which is connected to any 100 volt 60 cycle *a.c.* supply.

As most 60 cycle *a.c.* supplies are of 110 volts a rheostat is incorporated on the power amplifier panel to reduce the line voltage to 100. A volt meter is also incorporated on the amplifier panel so that the operator may see when he has the proper line voltage adjustment. The amplifier stage in this SPU is a conventional push pull amplifier stage utilizing two Radiotrons UX-250.

Field supply for the loud speakers is obtained from a high current Rectox rectifier.

The schematic inter-apparatus wiring diagram is shown in fig. 7,952 and gives a general idea of the layout of the equipment. In the case of a *d.c.* installation, a small motor dynamo set or rotary converter is used to supply the necessary *a.c.* for the SPU's.

Wiring for C Batteries.—The C, batteries for all UX-112A tubes are connected at their positive end to the movable arm

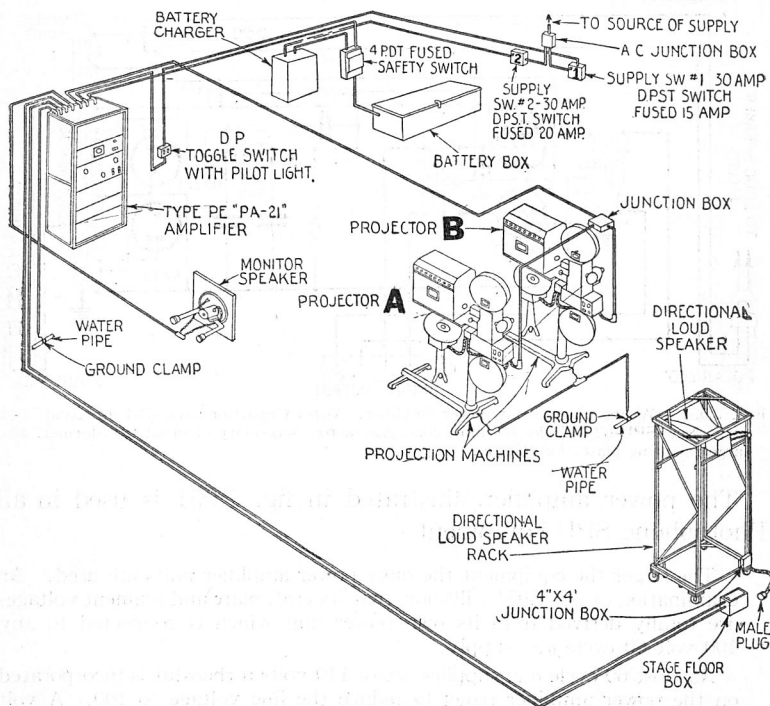


FIG. 7,952.—General layout of a typical RCA type PG-10 installation showing inter-apparatus run for directional loud speaker type installation. Exact location of RCA equipment to be determined by installation man; the directional loud speaker is to be mounted on rack so as to have the widest flare of the baffle in a horizontal and *not* in a vertical plane; stage floor box to be used on portable loud speaker rack installations only.

of the potentiometer. Proper taps are taken off the battery to give the correct C voltages. The 400 ohm resistor shown above the C battery furnishes by means of plate current RI drop, the grid bias for the UX-250 tubes. The 0.9 resistor to the right of the 400 ohm resistor is used as a fixed filament rheostat to give the proper voltage at the filament of the UX-112A tubes. To the right of this group of resistors, the C battery, and the condenser just mentioned are located and compensator, consisting of a tapped inductor and a variable resistor, which is connected in the circuit in such a fashion as to enable the operator to vary the tone quality of the output from the speakers to compensate for the ill effects of poor recording.

The condenser block and reactor shown above and to the right are connected so as to filter out the commutator ripple of the two dynamos and thereby eliminate any incident noise.

Voltage and Power Amplifier Circuits.—In fig. 7,950 is illustrated the voltage and power amplifier circuits of the PG-13 equipment. This unit is mounted on a steel base similar to that of the filter unit and is located within the same cabinet in the upper shelf. Three radiotrons UX-112A and four radiotrons UX-250 are used in this amplifier as previously stated.

The UX-112A's are connected in single stage cascade amplifying circuits while the radiotrons UX-250 are in a parallel push pull circuit.

The terminal board at the lower left hand corner of the diagram is connected to a corresponding terminal board in the filter unit as mentioned above. The first tube is coupled through an auto-transformer to the sound input from the projectors.

The plate circuit of the first tube is resistance coupled to the first inter-stage transformer which has a volume control connected across the secondary, this volume control thereby operating in the grid circuit of the second UX-112A.

The plate circuit of the second UX-112A is impedance coupled to the second inter-stage transformer and the third tube is resistance coupled to a push pull auto-transformer in the grid circuit of the radiotrons UX-250.

It may be seen that all tubes receive their plate supply from the +425 voltage terminal, having the voltage reduced to proper values by series plate resistors.

General Layout of Equipment.—Fig. 7,948 shows the general layout of a typical PG-13 installation and gives some idea of the layout of the equipment, although it must be understood that wide variations sometimes occur in practice due to the limitations of the construction of different theatres, and unusual power supplies, such as *d.c.* 25 cycle, *a.c.*, etc.

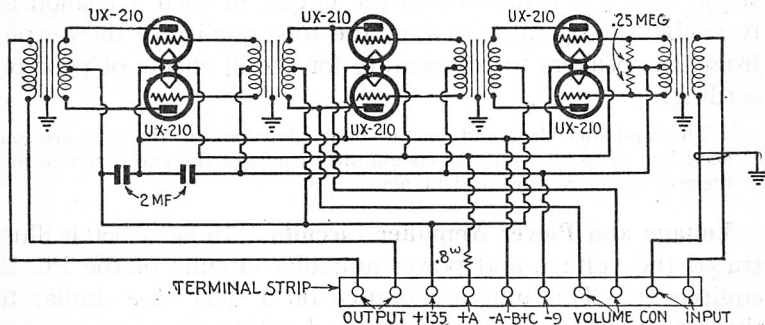


FIG. 7,953.—Wiring diagram for voltage amplifier.

Sound heads are provided for Powers, Simplex or Motiograph projectors. In general these sound heads are much the same as the sound heads used with SPU equipment but differ in that what is called an impedance type sound gate, is used.

In Photophone equipment type PG-1, 2, 3, 4, 6, 7, 8, and 10 equipment, the film is driven through the sound head by means of the constant speed sprocket which is driven through a viscous damping device.

This viscous damping device is a mechanical filter constructed with the purpose in view of eliminating the effects of mechanical vibration due to gear back lash, etc. This mechanical filter makes use of the cushioning effect of a spring drive damped by means of a grease lubricated friction device.

In the type PG-13 equipment another type of mechanical filter is used, consisting of a free running fly wheel which is friction driven by the film itself as it leaves the sound gate.

Any tendency for speed variation to be introduced into the motion of the film is effectively damped out by the inertia of the fly wheel. A sprocket driven at constant speed is located below the impedance roller and pulls the film through the sound gate and past the roller. The film is held in tension at the gate by means of springs.

Optical System.—The optical system used is similar to that used in other Photophone sound heads. The exciter lamp assembly, however, is entirely different from those used in other Photophone sound heads. Only one lamp will be put in position at a time and this is carried on an easily removable base so that the lamp can be set up and focused, then the entire assembly laid aside for emergency use while another exciter lamp is set up focused and left installed for routine operation. The UX-868 photo cell is used. The sound head contains an exciter lamp, ammeter and rheostat, together with the film disc transfer switch.

Type PG-10 Amplifier.—The type PG-10 equipment contains an amplifier rack containing a battery operated voltage amplifier and the necessary B, C and photo-cell polarizing batteries. This rack also contains a socket power unit operated power amplifier which derives voltages for grid, filament, and plate from a self contained power supply unit.

Two heavy duty storage batteries are used to supply the filament current of the voltage amplifier tubes and exciter lamps. Tungar rectifiers are used to charge the storage batteries. Two sound heads, two synchronous disc attachments, one booth monitor loud speaker and from one to four stage loud speakers with directional baffles complete the equipment.

The voltage amplifier used in all RCA Photophone SPU equipment except the PG-10 is shown in fig. 7,953.

As may be seen from examination of fig. 7,953, the voltage amplifier is a conventional push pull amplifier of three stages with transformer coupled

input and transformer coupled output. The tubes are operated at a plate voltage of +135 and a grid voltage of -9. The necessary filament voltage is obtained from a 12 volt storage battery mentioned previously. The 0.8 ohm resistor in the positive filament lead reduces the battery voltage to the proper value to light the tubes.

In fig. 7,953, the volume control is shown as a variable resistor connected across the plates of the second stage tubes, which permits of a remote volume control that operates without loss of quality.

The two *mfd.* condensers by pass the radio frequency currents around the B and C₁ batteries. The voltage amplifier is mounted on a steel base, all tubes operating in the vertical position. The type PG-10 voltage amplifier is similar in all respects with the exception that it uses UX-112A tubes and a grid circuit volume control instead of the plate circuit volume control. The grid circuit volume control does not permit a remote volume control and is therefore mounted directly on the amplifier rack. This amplifier is described rather than that of the PG-10 since the differences are very slight and this voltage amplifier in itself is representative of all other Photophone SPU equipment. The output of the voltage amplifier is sent to the amplifier shown in fig. 7,951.

TEST QUESTIONS

1. Draw a general layout of a typical sound system wiring installation.
2. Describe the amplifiers and tone control.
3. How is the wiring installed for the filter units?
4. How is a fader relay connected?
5. Describe the wiring for C batteries.
6. How are the voltage and power amplifier circuits installed?
7. Describe the general layout of equipment.

CHAPTER 204

Questions and Answers

(For Wiremen and Operators)

The following questions and answers relating to the various branches of theatre wiring give the code requirements and other valuable information:

Ques.—How many amperes are allowed on footlights, proscenium and side lights?

Ans.—15 amperes on a branch circuit fuse.

Ques.—What size wire is used for stage and gallery pockets?

Ans.—Minimum size wire for arc pockets; No. 6 B & S gauge; minimum size wire for incandescent pockets: No. 12 B & S gauge.

Ques.—Why must conduits and gas pipes be securely fastened in outlet boxes?

Ans.—To insure an effective ground. If a gas pipe be insecurely fastened to outlet box and should current pass over the conduit system, a hole might be burned in the gas pipe at the point of loose contact, causing a gas fire.

Ques.—What is the code ruling on dimmers?

Ans.—Dimmers must be wired so that they are dead when their respective circuit switches are open.

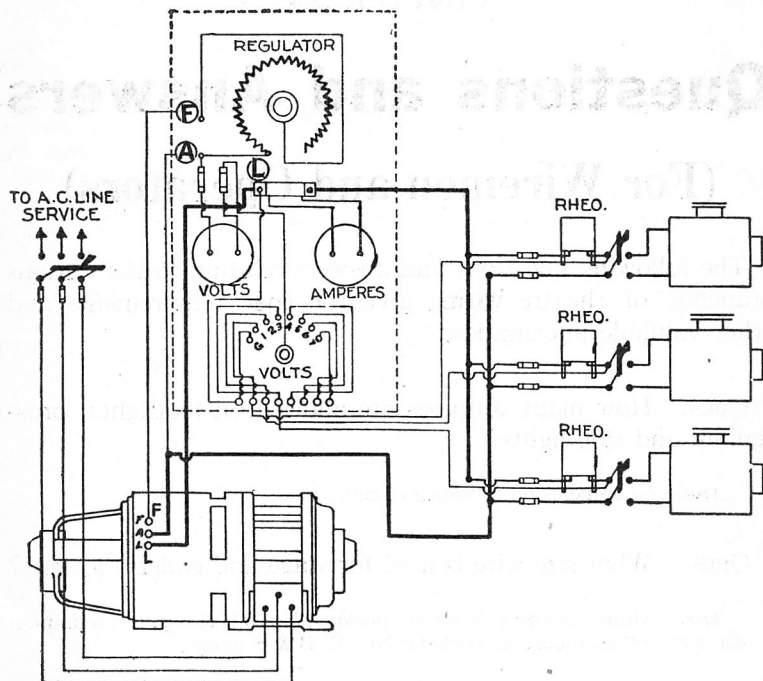


FIG. 7,954.—Wiring diagram of three phase multiple arc transverter.

Ques.—Festooned lighting on stage enclosed in lanterns, what is the code ruling?

Ans.—Joints should be staggered and metal lamp guards must be used.

Ques.—Where two services are installed in a theatre, what capacity on each service?

Ans.—One service shall be of sufficient capacity to supply current for the entire equipment of the theatre. The other of sufficient capacity to supply the emergency system.

Ques.—What is the difference between professional and non-professional moving picture machines?

Ans.—The professional type machine must be enclosed in an approved booth. In charge of a qualified attendant. Use an electric arc as the source of illumination. The non-professional type machine is so constructed that it is not possible to use full sized commercial film. An incandescent lamp must be used as the source of illumination. The machine

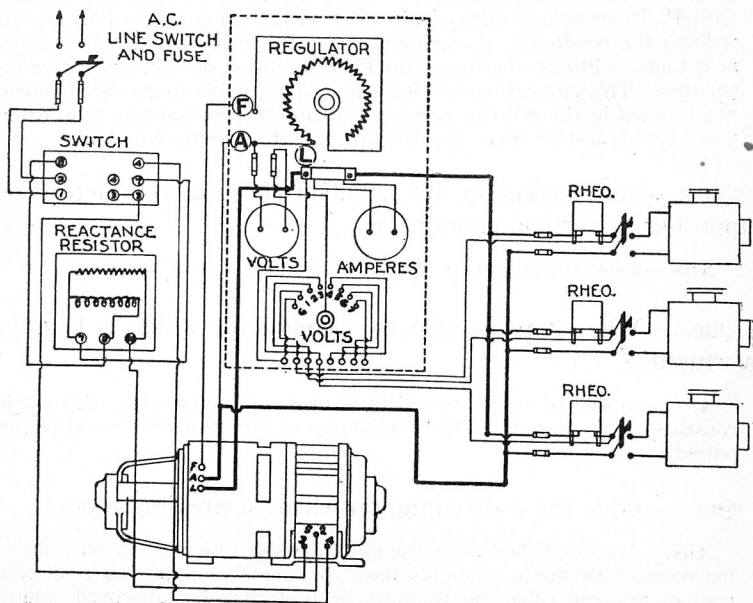


FIG. 7,955.—Wiring diagram of single phase (split phase starting) multiple arc set.

should be marked "For use with slow burning film only." Machines using slow burning film only are approved for use without booth.

Ques.—How must a motion picture booth be ventilated?

Ans.—By means of a vent pipe having a cross sectional area of not less than 78 sq. ins. and this vent should lead to the outside of the building or to a special non-combustible flue. Draft in vent pipe must be maintained by an exhaust fan having a capacity of 50 cu. ft. of air per minute, connected on emergency service, controlled outside booth.

Ques.—What precautions and requirements must be observed in the installations of storage batteries? Give reasons for these requirements.

Ans.—Storage battery rooms must be ventilated. Because of the danger from gas fumes when charging. Wiring should be exposed and painted with P. B. or similar compound. The wiring being exposed to the air reduces the possibility of corrosion of the insulation and conductors by acid fumes. Storage batteries should be mounted on non-absorptive insulators. This reduces current leakage, Metal liable to corrosion should not be used in the cell connections. Because metal that has been eaten away having lost its area, the carrying capacity is reduced.

Ques.—How should 0, 00, 200,000 *cm.* size conductors be supported in vertical conduit?

Ans.—0 size 100 ft.; 00 size 80 ft.; 200,000 *cm.* size 80 ft.

Ques.—What may happen to a conductor which is heavily overfused?

Ans.—In case of excessive load the wire would become hot, this would constitute a fire hazard. The effectiveness of the insulation would be impaired.

Ques.—Give the code ruling on wiring a dressing room.

Ans.—Approved conduit or armored cable must be used to wire dressing rooms. Pendants for lights must be made of approved reinforced cord or armored cable, lamps must be protected by approved guards locked in place.

Ques.—What services are required to be installed in a theatre?

Ans.—Two separate and distinct services. One for the emergency lights. One for general lighting and power.

Ques.—Give the allowable carrying capacities of at least five different sizes of wire with which you are familiar.

Ans.—No. 18, 3 amp.; No. 14, 15 amp.; No. 12, 20 amp.; No. 6, 50 amp.; No. 1, 100 amp.; No. 00, 150 amp.

Ques.—What are the insulation resistances of a building between conductors and ground of 25, 100, 400 amperes?

Ans.—Up to 25 amperes, 800,000 ohms; up to 100 amperes, 200,000 ohms; up to 400 amperes, 50,000 ohms.

Ques.—How should lights on scenery be installed?

Ans.—Fixtures should be wired internally. The fixture stem carried through to the back of the scenery and the end bushed. Fixtures should be fastened securely in place on scenery.

Ques.—On portable bunches, how should they be installed?

Ans.—Substantial metal should be employed in their manufacture. The wiring should not be exposed. Where the cable passes through the metal an approved bushing must be used. The cable must be anchored in such a manner that no strain will be brought to bear on the connections. Bunches must be kept clear of inflammable materials. Standards should not be grounded.

Ques.—How should lamp be installed in scene dock?

Ans.—Lamps installed in scene docks should be so located and guarded as to be free from mechanical injury. Lamp guards must be used.

Ques.—How should a motor generator be installed in a motion picture booth?

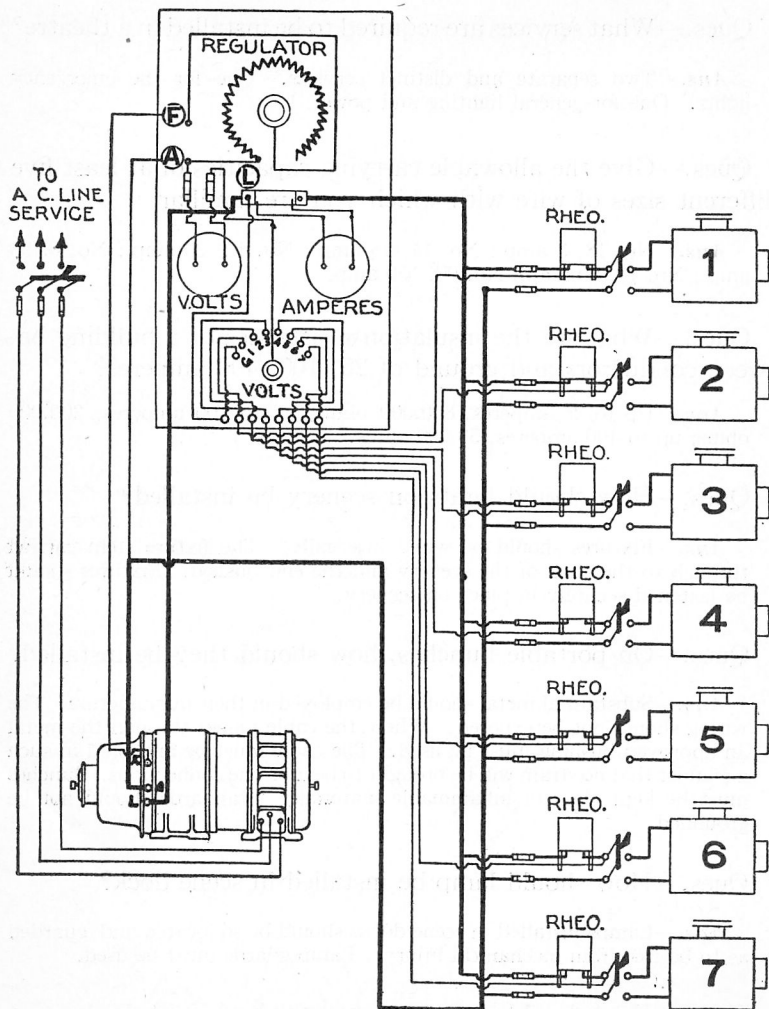


FIG. 7,956.—Wiring diagram of three phase multiple arc set showing control panel with volt meter selector switch.

Ans.—Of the totally enclosed type, conductors brought in conduit to box incorporated on motor frame, motor generator so located that it will not be in the way of M. P. operator. Properly grounded, and a disconnecting switch within sight of motor.

Ques.—What size wire is used for motion picture machine?

Ans.—The minimum No. 4 B & S gauge. Wires should be of sufficient carrying capacity for the current rating of the projector.

Ques.—How must emergency light be installed?

Ans.—On emergency service controlled from the front of the theatre.

Ques.—In stage flues and dampers how can same be controlled?

Ans.—If electrically controlled, on a closed circuit, by two single pole switches each in box with a self closing door, without a lock or latch. One at the electrician's station, the other at a place designated by the commissioner. The release device should be designed to operate at the voltage of the circuit on which it is installed.

Ques.—Why is a single phase 3 wire system used for lighting even in cases where it is necessary to introduce a 2 phase service to a building because of its power load?

Ans.—Because of the voltage fluctuation when starting motors. If trouble develop on power service, lighting service will not be interfered with.

Ques.—Where border lights are installed what kind of wire should be used?

Ans.—Slow burning wire for circuit wiring. Border light cable where flexibility is required.

Ques.—If a tap of No. 14 B & S gauge wire had to be taken off a main of No. 10 gauge wire, when would it be permissible to omit fuses where the wire size changed?

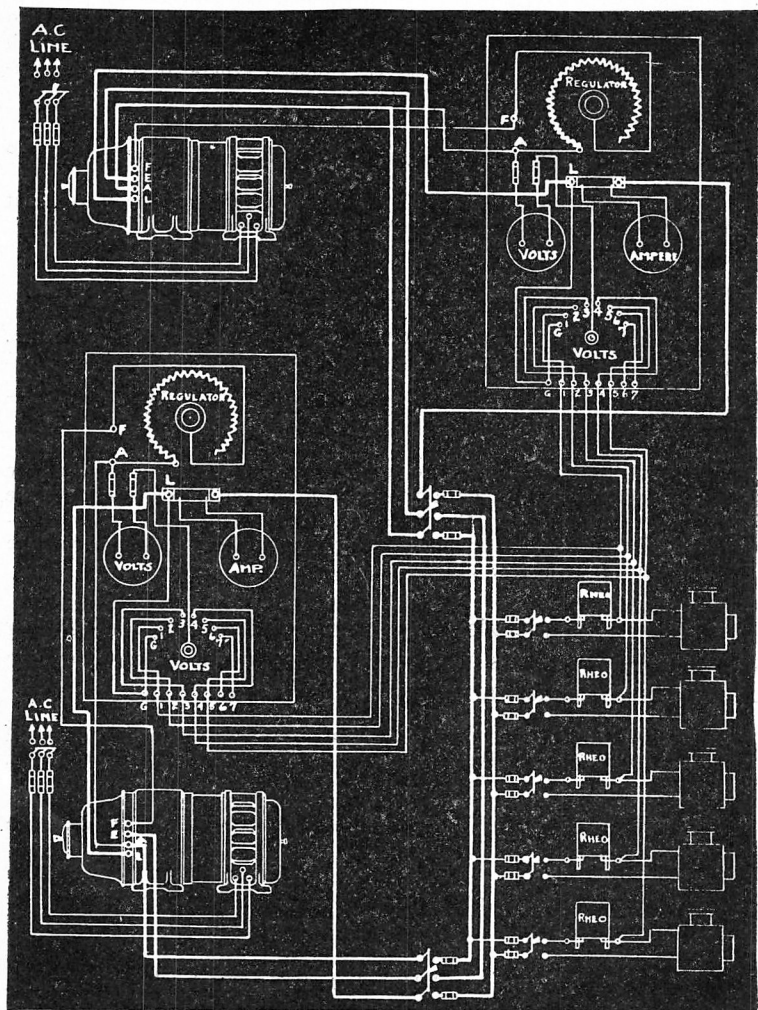


FIG. 7,957.—Wiring diagram showing installation of two multiple arc units in parallel and control panel.

Ans.—Fuses may be omitted where an extremely short tap from a No. 10 main is connected by No. 14 wire to a cut out or wherever the fuse in the larger wire will protect the smaller wire.

Ques.—Give in detail how to wire a moving picture booth for current for two standard moving picture machines, one motor generator set and 3-60 watt lamps. Give sketch.

Ans.—All conductors should be installed in rigid conduit. Run set of feeds to motor of motor generator set as per requirements of motor, from the output side of motor generator set run 2 No. 00 B & S gauge conductors to a distribution panel, from the panel 2 No. 4 B & S gauge conductors to each M.P.M. outlet. Run 2 No. 14 B & S gauge wires to booth for lighting fed from emergency panel. Run 2 No. 12 wires to exhaust fan outlet fed from emergency panel. Run 2 No. 14 B & S gauge wires from distribution panel to each drive motor outlet. All motors, motor generator set, and other electrical apparatus well grounded. At distribution panel 1 switch for each motion picture machine, and 1 switch for each drive motor. Exhaust fan switch located outside booth. Lighting switch in booth.

Ques.—What is the Code ruling on portable plugging boxes?

Ans.—Live parts enclosed. Each receptacle should have a current carrying capacity of 30 amps. and be protected by fuses enclosed in a fire-proof box with self closing doors. Bus bar capacity equal to total capacity of outlets. Master cable connected by lugs to box.

Ques.—How should a curtain motor be installed?

Ans.—With all live parts totally enclosed. Chain, gears, etc., clear of scenery wires brought in conduit, direct to box on motor frame. Drip pan, frame grounded. Switch at motor which will disconnect all wires from same.

Ques.—State all the rules that you can recall covering the installation of curtain motors on the stage of a theatre.

Ans.—Gears, chains, and all moving parts of motor guarded so they cannot come in contact with scenery. A switch incorporated in the motor unit itself. Type motor totally enclosed. Should be located overhead if possible. Connections at motor totally enclosed. A switch should be in circuit to disconnect all live wires from same. Should be grounded.

Ques.—How should dimmers in theatre wiring be wired with respect to the balance of the circuit of which they form a part?

Ans.—Half the lights of each border, foots, etc., should be on one side of 3 wire circuit and the other half on the other side. As one switch controls each individual border light, etc., and this switch is double pole each side being on a live leg of different polarity the balance will be absolute. The dimmer is placed in series with each outside line.

Draw a diagram of a break down switch connecting street service and a private plant.

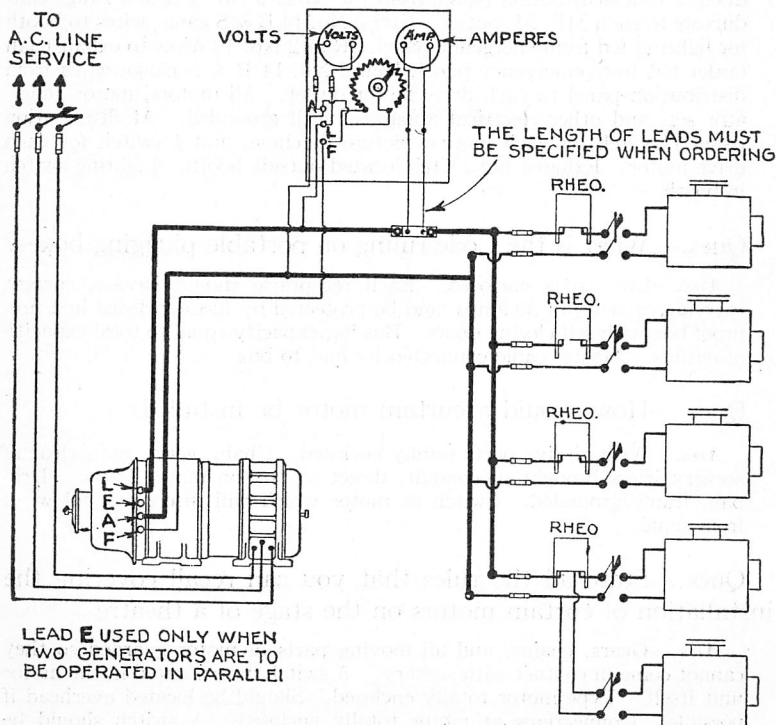


FIG. 7,958.—Wiring diagram of multiple arc transverter, three phase motor.

Ques.—What rules cover the service for motion picture house or theatre?

Ans.—Two distinct services. If one service to building the emergency service shall be hooked up ahead of the main fuse on street side of general service, and only one set of fuses between service fuses and outlets.

Ques.—How must motors of 550 volts be installed?

Ans.—Motors of this type are to be installed in power house, sub-station, etc., or in a room especially designed for the purpose. Switch at motor. Frame effectively grounded. Leads carried in conduit direct to box on motor frame. No live part exposed, and must be provided with drip pan.

Ques.—How should motor and rheostats be installed in film storage vault?

Ans.—This is forbidden.

Ques.—Name all the reasons you can that would cause excessive sparking at the brushes of a compound wound motor.

Ans.—*a*, Loose shunt field connection; *b*, bad condition of commutator; *c*, bad condition of brushes; *d*, open circuit in armature; *e*, bad adjustment of brushes; *f*, overload.

Ques.—How would you wire a moving picture booth for the machine and for lighting? Draw diagram of connections, give wire size and names of various appliances.

Ans.—Principal parts of projector are: drive motor; automatic shutter; auto. arc feed; intermittent movement; enclosed switch for arc; enclosed switch for motor; all wiring in rigid conduit; 3 No. 1 B & S gauge conductors installed as feeders, to a distribution panel in the booth. From this distribution panel 2 No. 4 B & S gauge wires to each M.P. machine outlet, also 2 No. 14 B & S gauge wires to each drive motor outlet. Individual switch for each moving picture machine and drive motor in panel. Two No. 12 B & S gauge wires feeding exhaust fan outlet, fed from emergency panel. Exhaust fan switch outside booth. Two No. 14 B & S gauge wires for lighting circuit fed from emergency panel switch in booth.

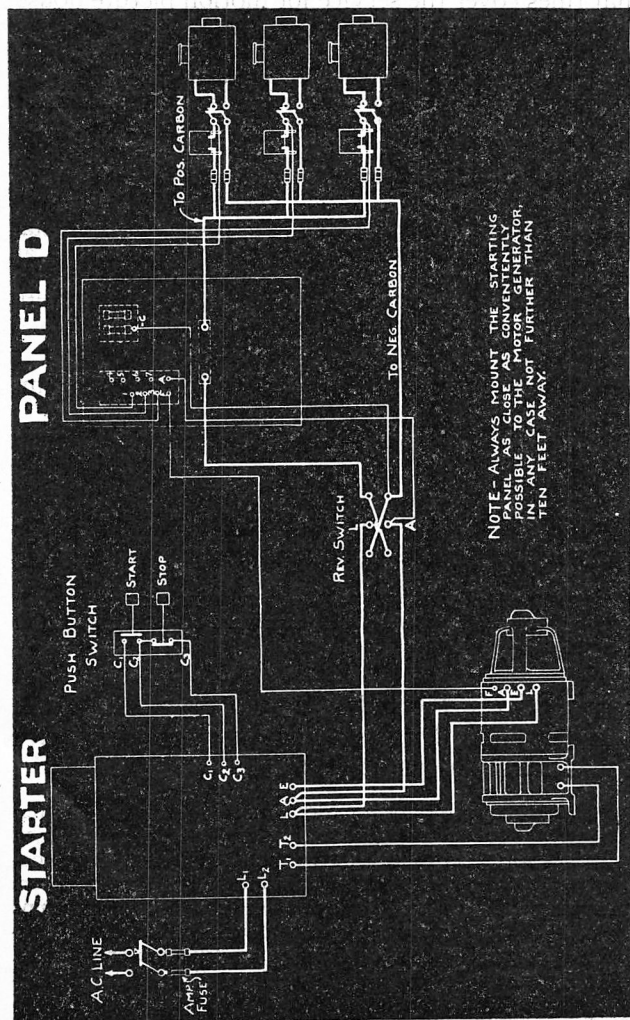


Fig. 7,959.—External wiring diagram of Hertner single phase transverter starter and panel D. The push button station, panel D, and the reversing switch can be located wherever desired. **Wiring Instructions.** Connect L-1 and L-2, in the starter to the a.c. line. Connect T-1 and T-2, in the starter to the a.c. motor. Connect L, A and E, in the starter to L, A and E, on the dynamo. Connect F in the panel D, to F, on the motor dynamo. Connect L and A, in the starter to the center posts of the reversing switch. Connect C-1, C-2 and C-3, to the push button station which can be located at any desired point. Connect one jaw post of the reversing switch to the negative lamp bus. Connect the other jaw post of the reversing switch to L, in the panel D. Connect the C terminal in the panel D, to the positive lamp bus. Connect the C terminal in the panel D,

FIG. 7,959.—Text continued.

to the jaw post of the reversing switch to which the negative lamp bus has been connected. Connect the A, terminal in the panel D, to the hinge post of the reversing switch to which the A, lead from the starter has been connected. All connections are now complete and after the dash pot has been fitted with oil and replaced on the relay the unit should start when the starting push button is pressed. In making connections be sure that the wire sizes used are not smaller than noted on the diagram. **Fuses.** The a.c. fuses directly ahead of the starter must be of large enough capacity to carry the maximum load of the machine. **Operating instructions.** When the start button is pressed the unit will immediately start and with the reversing switch closed to one side, the meter will read properly or the needle will go off the scale past the zero point. In other words the polarity will be reversed. If this be the case it is only necessary to throw the reversing switch to the other position so that the meters will read properly. When the meter reads properly the polarity to the lamps will be correct. This motor dynamo will supply current at approximately constant voltage up to the capacity of the machine. The unit is designed to carry the high ampere load for such time as is required to burn in carbons or warm them up preparatory to a change over. The field regulator in the panel provides a means of adjusting the voltage of the dynamo to the correct operating voltage. **Starter operation.** As soon as the start button is pressed the four pole a.c. contactor will close. This connects the dynamo to the a.c. line and will permit the unit to start. At the same time the push button is pressed the dash pot relay is energized and this relay should close after the unit has come up to running speed. When the dash pot relay closes, the coil to the two pole a.c. contactor is energized, and as this contactor closes, the circuit to both the four pole contactor and the dash pot relay is opened so that only the a.c. motor is connected to the a.c. line. If the two pole contactor close too soon, further adjustment should be made on the dash pot relay by closing the oil inlet valves and turning down the plunger.

Ques.—In general, what are the principles governing the installation of electric heaters?

Ans.—Should not be located in dusty or linty places. Heating devices must have name plates as a guide to installation thereof. Smoothing irons must have an approved stand. Pilot or indicating lamps are advisable. A heater consuming over 250 watts must be fed by heater cord. Heaters of 6 amp. may be used on branch circuits. Heaters over 10 amps. must have an indicating switch. Switches must disconnect all ungrounded wires from circuit. Key sockets should not be used. Ground wires to heaters must be bolted securely to same, soldering is not acceptable.

Ques.—In wire for special electrical effects, what is the code ruling?

Ans.—Screened and so constructed that sparks cannot come in contact with inflammable material.

Ques.—What size ground wire should be used for: *a*, 0 to 100 amp.; *b*, 101 to 200 amp.; *c*, 201 to 500 amp.; *d*, over 500 amp.?

Ans.—The following size wires B & S gauge: *a*, No. 10; *b*, No. 6; *c*, No. 4; *d*, No. 2.

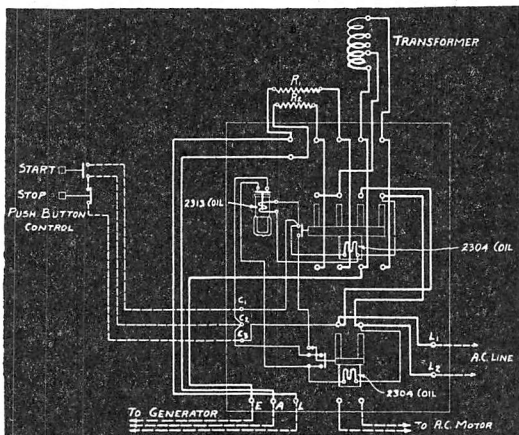


FIG. 7,960.—Back of board diagram of Hertner single phase starter 3 wire control, timing relay.

Ques.—How would you change the direction of 3 phase *a.c.* induction motor?

Ans.—By interchanging any two of the motor lead connections.

Ques.—What are emergency lights in a theatre as described in the Electrical Code?

Ans.—Exit lights, light in corridors, stairways, lobbies, and all other lights normally kept lighted during the performance.

CHAPTER 205

Television

By definition, television is *vision obtained of a distant object through a telegraphoscope or instrument involving the use of selenium cells for telegraphically transmitting a picture.*

The problem of television broadly is that of:

1. Converting light signals into electrical signals.
2. Transmitting the electrical signals to a distant station.
3. Converting the transmitted electrical signals back into light signals.

Given means for accomplishing these three essential tasks, the problem becomes that of developing these means to the requisite degree of sensitivity, speed, efficiency, and accuracy, in order to recreate a changing scene at a distant point, without appreciable lapse of time, in a form satisfactory to the eye.

A convenient starting point for the discussion of television is the human eye itself.

In this an image is formed upon the retina, a sensitive screen, consisting of a multitude of individual light sensitive elements. Each of these elements is the termination of a nerve fibre which goes directly to the brain, the entire group of many million fibres constituting the optic nerve.

A theoretically possible television system could be made by copying the eye.

Thus a large number of photo-sensitive elements could be connected each with an individual transmission channel leading to a distant point, and signals could be sent simultaneously from each of the sensitive elements to be simultaneously used for the re-creation of the image at the distant point. The number of wires or other communication channels demanded in a television system of this sort would be impractically large.

For practical purposes, reduction of the number of transmission channels is made possible by the fact that, while in vision all parts of the image on the

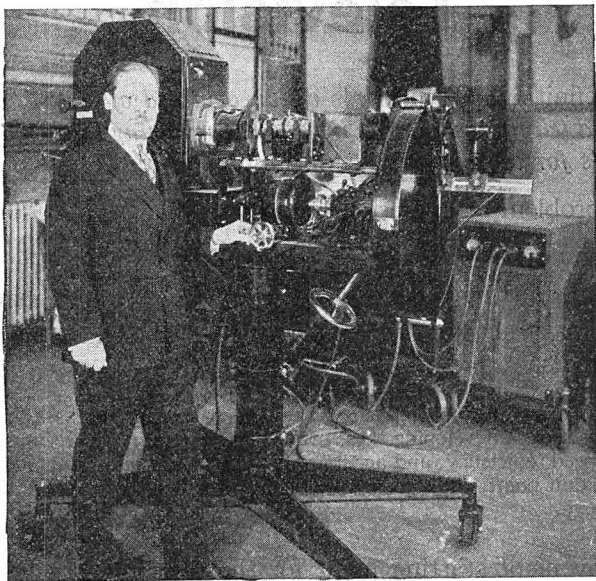


FIG. 7,961.—Dr. E. F. W. Alexanderson, engineer in charge of the radio consulting department of the General Electric Company, with his television apparatus which projects the picture on the theatre screen.

retina are simultaneously and continuously acting to send nerve impulses, the inertia of the visual system is such that a sensation of continuity is obtained from discontinuous signals, provided these succeed each other rapidly enough.

This sensation of continuity is due to what is called the *persistence of vision*. It is immaterial to the eye whether the whole view be presented

simultaneously or whether its various elements be viewed in succession, provided the entire image be traversed in a sufficiently brief interval. This accordingly permits as a basic principle of television, what is known as *scanning*.

In television *scanning* is defined as *running over the elements of the image in sequence, instead of endeavoring to transmit all of the elementary signals simultaneously*.

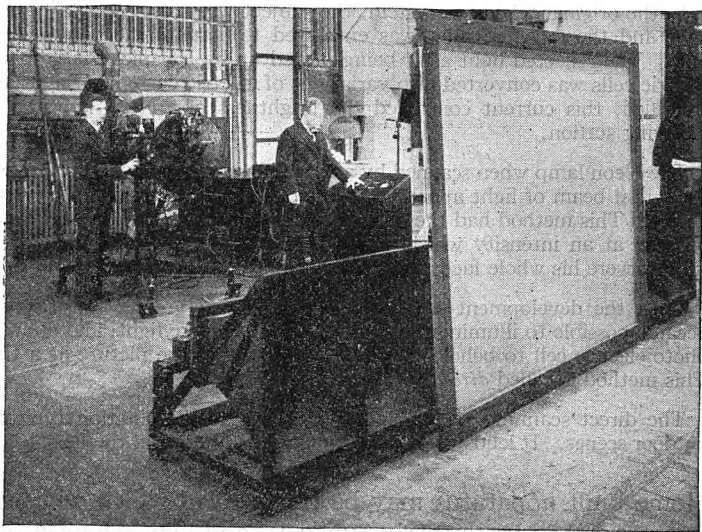


FIG. 7,962.—The 6 by 7 foot screen upon which television pictures are projected, in a Schenectady theatre. When in use curtains are dropped about the sides and top of this special screen.

The development of a television system therefore necessitates, at an early stage, the design of some scanning system by which *the image to be transmitted may be broken up into sequences of signals*.

In the simplest case, where one transmission channel is to be used, the whole image will be resolved into a single series of signals.

Scanning is accomplished by means of a scanning device which makes possible the decomposing of an image into a large number of small images for the purpose of transmission.

There are two methods of scanning known as:

1. Beam;
2. Direct.

In the original television system, the subject was scanned by a beam of light and the reflected light was employed to actuate the photo-electric cells. The reflected light after being picked up by a bank of large photo-electric cells was converted into variations of electric current. Sufficiently amplified, this current controlled the brightness of a Neon lamp at the receiving station.

The Neon lamp when scanned by a moving aperture in synchronism with the initial beam of light appeared to the observer to re-create the original object. This method had the decided advantage that artificial light could be used at an intensity which would be decidedly uncomfortable for the subject were his whole face illuminated at once.

With the development of photo-electric cells of greater sensitivity, it became possible to illumine the subject broadly by daylight, and allow the photo-electric cell to behold only one small area of the picture at a time. This method is called *direct scanning*.

The direct scanning system requires the broad illumination typical of outdoor scenes. It lends itself to action at a distance from the lens.

Home built apparatus may be constructed which will bring in pictures, if it be properly tuned to and synchronized with a transmitting station which happens to be broadcasting pictures. The system which shows promise for the home construction is that known as the scanning disc.

In construction a number of holes are drilled near the outer surface of a scanning disc in a spiral. The number of holes in the disc determines the number of vertical or transverse divisions in the picture. To secure the best clarity or definition with a given number of small images, or dots, the width of each dot should equal its height. This makes it advisable to have a square image.

Since the number of holes in the disc determines the number of dots in one direction, and since the picture is to be square, it follows that the total number of dots is equal to the square of the number of disc holes. If, for example, the disc have 48 holes, then the image will be decomposed into 48×48 , or 2,304 dots at the transmitting end.

The receiving process recomposes these 2,304 dots of different intensity into an image. These must be reassembled or composed in the same order and at the same speed that obtained at the transmitting end.

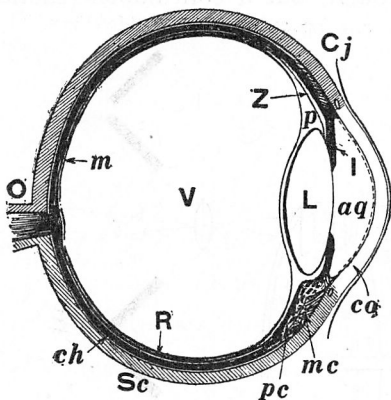


FIG. 7,963.—Section through eye ball. *The parts are:* Cj, conjunctiva; co, cornea; Sc, sclerotic coat; ch, choroid coat; pc, ciliary processes; mc, ciliary muscle; O, optic nerve; R, retina; I, iris; aq, anterior chamber containing aqueous humor; L, lens; V, vitreous humor; Z, zonule of Zinn, which supports the lens; p, space known as the canal of Petit; m, position of the macula, or yellow spot.

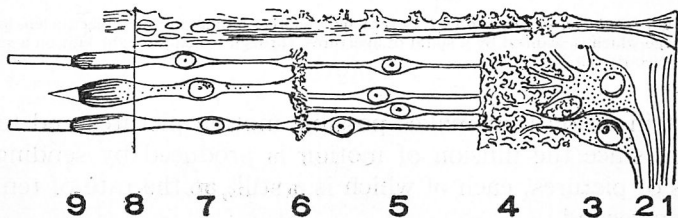


FIG. 7,964.—Diagrammatic section of the retina, showing its various layers, which are numbered as in the illustration. The first layer consists of nerve fibres, the ninth is the layer of rods and cones. The tenth layer, of pigment cells beyond the rods and cones, is not shown.

Persistence of Vision means that *the electro-chemical process taking place in the nerves and the brain, as a result of a stimulus on the retina, persists for a brief time after the stimulus has been removed.*

Persistence lasts for about one tenth of a second; so if a series of stimuli be applied to the eye at that interval the result will be, not a broken, but a continuous reaction. It is this

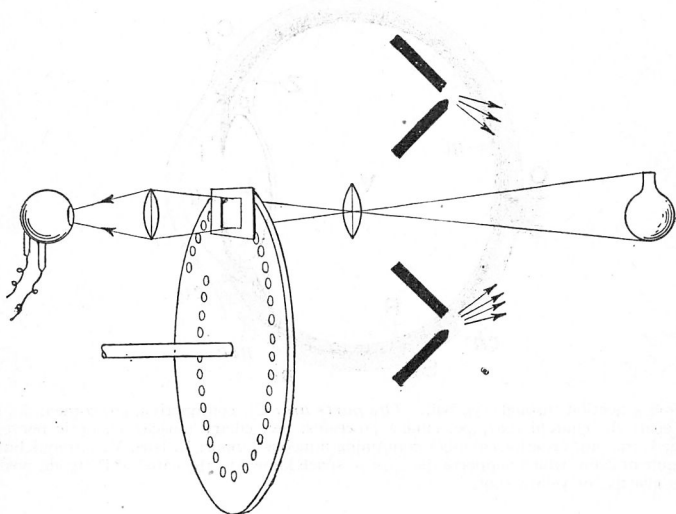


FIG. 7,965.—**Television principles 1.** Several light sources illuminate the subject; a lens forms an image which is scanned by a spiral of apertures, through which the light falls on a single photo-electric cell.

defect in vision that makes possible motion pictures and television, since the illusion of motion is produced by sending a series of pictures, each of which is a still, at the rate of ten or more a second.

The operation and advantages of the scanning method actually used in the present process for transmitting television

images may be better understood by first considering a simple and analogous method illustrated in fig. 7,965.

The subject is illuminated by lights placed in front of it as shown. A lens forms an image of the subject on the rotating disc. This disc is pierced with a series of small holes or apertures arranged in the form of a spiral; and, as the disc rotates, the apertures trace across the image one after the other in a series of parallel lines.

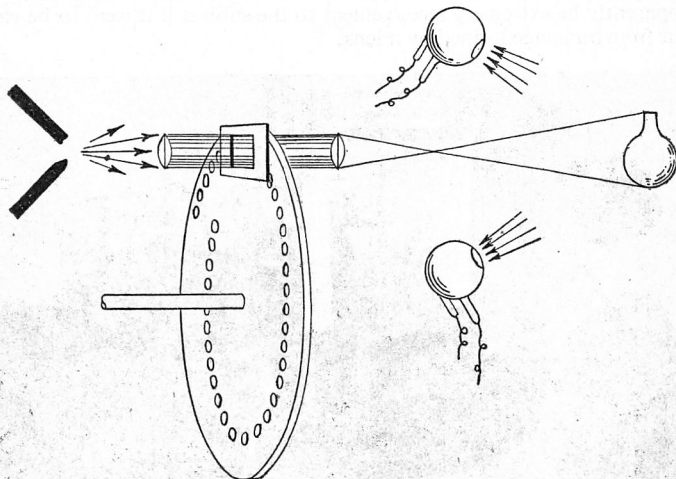


FIG. 7,966.—*Television principles 2.* Light from a single source is projected as a small moving spot on the subject; the reflected light is received by several photo-electric cells.

The frame limits the size of the image and prevents more than one aperture being in the image at one time.

Light, passing through an aperture as it travels across the image, falls in the light sensitive cell and generates a picture current proportional to the brightness of the image from point to point along steps taken one after the other across the image.

In any system, such as that outlined above, which depends upon scanning an image of the view as formed by a lens, the efficiency of the system is ultimately limited, for any given

size of image that can be scanned, by the ratio of aperture to focal length of the best lens that can be secured.

Experiments show that, with the best lens available to form a one inch square image, it would be necessary to illuminate a subject with a 16,000 candle power arc at a distance of about four feet in order to secure an image bright enough for a photo-electric cell to give an output current above the noise level in an amplifier system. In other words, television would apparently be extremely inconvenient to the subject if it were to be carried out from an image formed by a lens.

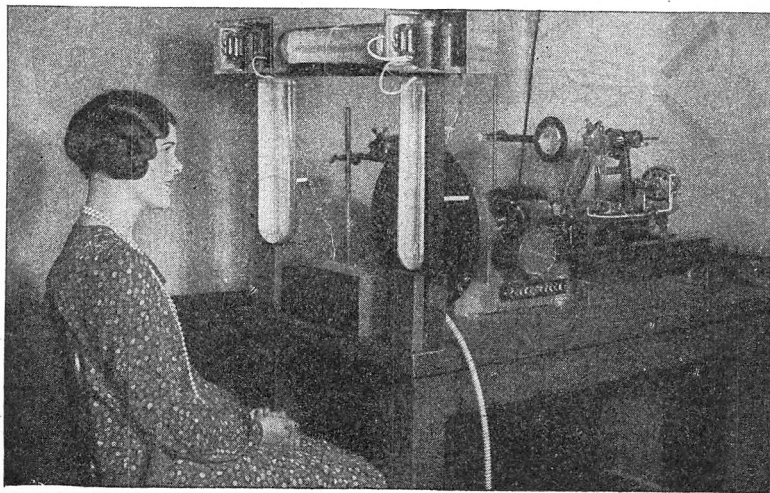


FIG. 7,967.—Television apparatus. Light from the arc lamp is condensed on the disc, which is driven by a high frequency synchronous motor. The disc carries a spiral of pin hole apertures.

In the system actually used for television transmission, this apparent limitation has been evaded by reversing the entire optical system of fig. 7,965, and arranging it as shown diagrammatically in fig. 7,966. Instead of scanning an image of the subject, the actual subject is scanned directly by a rapidly moving spot of light.

An illustrative laboratory set up, fig. 7,967, shows the arrangement of parts in such a transmitting station. A fifteen inch disc rotating approximately eighteen times per second carries a series of fifty small apertures

arranged in the form of a spiral. A beam of light is condensed by a lens from a 40 ampere Sperry arc to intensely illuminate a limited area in the path of the moving apertures; and a slender, intense beam of light passes through each aperture as it moves across the illuminated area. A frame in front of the disc permits light to emerge from only one aperture at a time and the lens in front of the disc focuses an image of this moving aperture on the subject. As a result of this arrangement the subject is completely scanned in a series of successive, parallel lines by a rapidly moving spot of light, once for each revolution of the disc; and on account of the transient nature of the illumination the subject is scarcely aware that he is being exposed to it.

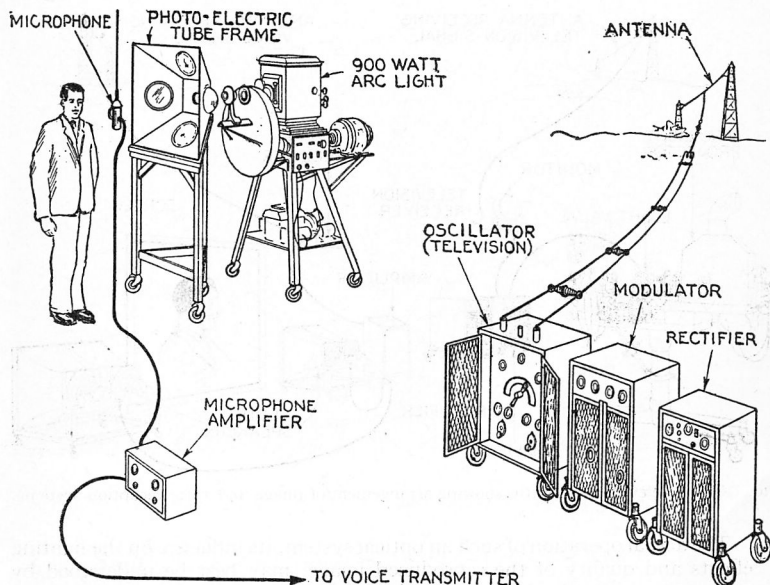


FIG. 7,968.—Television pick up apparatus. At the studio, feeding into transmitter.

As the spot of light traces across the subject, light is diffusely reflected or scattered from the subject in all directions, and some of the light that is reflected forward passes

into three large photo-electric cells placed just in front of the person who is being viewed.

The current outputs from the three photo-electric cells operate in parallel into a common amplifier system. As the beam of light passes, for instance, across the person's eyebrow less light is reflected to the photo-electric cells, and as the beam passes across his forehead more light is reflected. Since the current output from the photo-electric cells is proportional to the received light, the current follows accurately the brightness of the various elemental areas of the subject's features as he is traced over by the scanning beam. The fluctuating current is uni-directional.

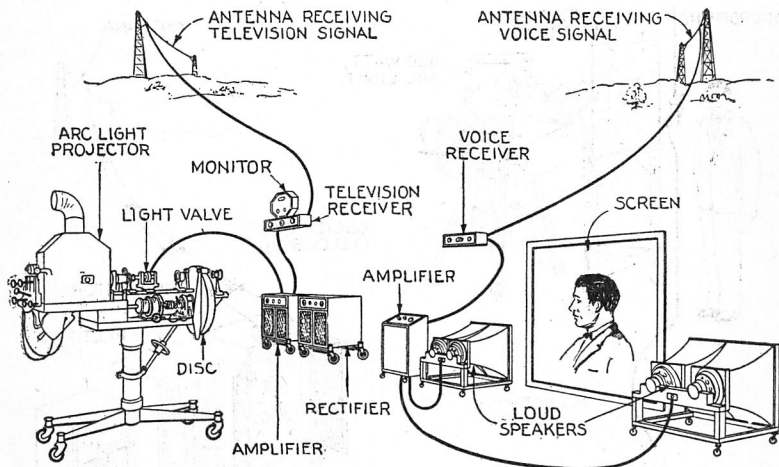


FIG. 7,969.—Television apparatus showing arrangement of image and voice reception systems.

The actual operation of such an optical system, its influence on the lighting effects and quality of the reproduced image, may best be understood by noting that optically the system is identically the same as if all of the rays of light were reversed in direction to give an optical system equivalent to fig. 7,965.

The television apparatus sees the subject exactly as if rays of light came out of the photo-electric cells to illuminate the

subject; the lens formed an image of the subject on the disc, and the apparatus scanned this image and reproduced it at the receiving end.

The lights and shadows seen in the image are the same as if the subject were illuminated by three large lights in the positions of the photo-electric cells and looked at from the position of the lens.

It also follows from the considerations that, within its range of resolving power, this scanning method will not only reproduce a plane subject, such as a drawing, but it will also faithfully reproduce three dimensional figures with sharp edges and elevations and depressions, just as well as they could be reproduced in a photograph.

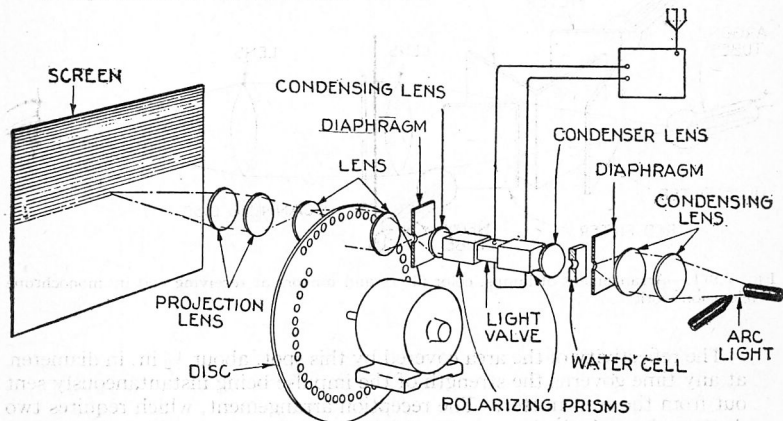


FIG. 7,970.—Elementary television diagram showing details of the Karolus system; the water cell removes heat rays; the Nicoll polarizing prism at the right polarizes the light; the light valve (Kerr cell) then rotates the ray, to a degree which determines the amount to be cut off by the polarizing prism at the left; and the light spot is then caused to move over the screen, reproducing the image.

In addition, because the light passes in an approximately parallel beam through a disc aperture, the slender beams of light sweeping across the region in front of the transmitter just barely overlap each other even at a considerable distance from the apparatus. Consequently, it is not necessary that the subject be at the exact positions at which the small apertures are sharply focused; and within wide limits no confusion results as the subject moves toward or away from the apparatus. The brightness as well as the size of the received image decreases as the subject moves away from the

photo-electric cells; and for good transmission of the human features, which reflect very little blue light to which the photo-electric cells are sensitive, a person should not be more than a few feet away from the cells.

At the studio, the person to be televised stands before a bank of photo-electric cells as in fig. 7,968, while a large lamp casts a ray of light, which is directed by the scanning disc, over the features of the subject.

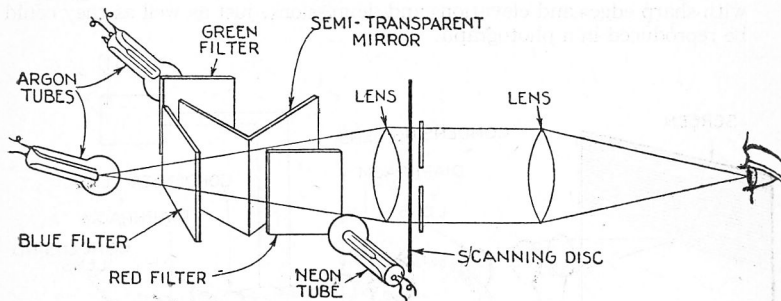


FIG. 7,971.—Arrangement of lamps, color filters and mirrors at receiving end in monochrome television work.

The reflectivity of the area covered by this spot, about $\frac{1}{2}$ in. in diameter, at any time governs the strength of the impulse being instantaneously sent out from the transmitter. The reception arrangement, which requires two distinct channels, is shown in fig. 7,969. The television signal on 140 meters is picked up, amplified and conducted to the projector, at the left of the figure.

Television in Colors.—The method here described is the *beam scanning method*. In this method *the positions of light source, image forming lens, and sensitive surface, in photography, are reversed*. The lens projects a narrow moving beam of light and the light reflected from the object is picked up by photo-electric cells which occupy the positions which in photography would be taken by the light sources.

In more detail, the essential feature of the beam scanning method of three-color television consists in the use of three sets of photo-electric cells, one set with its accompanying filters recording the red constituent, the second the green and the third the blue constituent of the image. The light source and the scanning disc are in no way altered from the form as used in monochrome television. The three sets of cells are each connected to a separate communication channel, and the television signals going over these three channels correspond to the three colors.

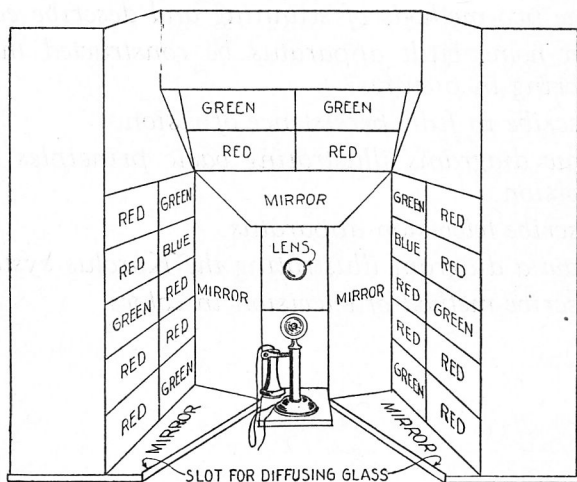


FIG. 7,972.—Arrangement of photo-electric cells for three color television.

At the receiving end a number of possibilities are open; one of these is the projection of three colored beams of light on to the same spot on a screen, which would correspond to a three-color lantern projector; a second possibility is the use of a triple grid vacuum tube similar to the large grid which has been used previously for exhibiting television images to an audience, except that three juxtaposed sets of tubes would be used with three distributors. A third possibility, which is the one used in this work, is to superpose the light from three different colored television glow lamps by means of semi-transparent mirrors. This is comparable to the additive superposition in three-color photography exemplified in the chromoscope.

TEST QUESTIONS

1. *What is television?*
2. *How is television accomplished?*
3. *Explain the physics of the human eye.*
4. *What is understood by persistence of vision?*
5. *Define scanning.*
6. *Name two methods of scanning and describe each.*
7. *Can home built apparatus be constructed that will bring in pictures?*
8. *Describe in full, persistence of vision.*
9. *Draw diagrams illustrating basic principles of television.*
10. *Describe television apparatus.*
11. *Draw a diagram illustrating the Karolus system.*
12. *Describe method of television in colors.*

